Why is the Western Electric 25B the *most popular* speech input console in broadcasting?

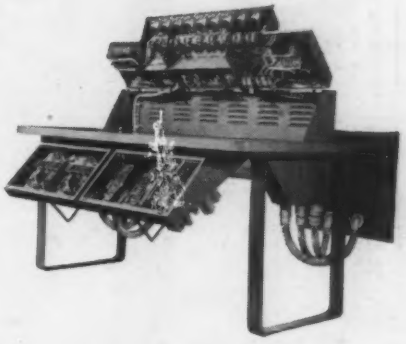
To date, more than 225 FM, AM and TV Stations have installed the 25B. Here are reasons for such popularity:

General Advantages

1. It provides highest quality studio control for AM and FM at their best.
2. It's versatile... handles two studios... has two main channels for simultaneous operation.
3. It's easy to operate, because all controls are functionally located.
4. It's a complete unit with its own table... attractive, sturdy, well designed... and it's moderately priced.

Technical Advantages

1. It covers complete FM frequency range. Has exceptionally low distortion and high signal-to-noise ratio.
2. It is easy and economical to install... plug-in cables carry all external leads to wall boxes.
3. It's designed for complete accessibility... see how it opens up to expose all components.
4. It includes... 7-position mixer; line and microphone transfer keys; dual volume indicators; separate built-in tube check meter; regulated power supply; and many other important features.



What about deliveries? 25B's are being produced in large quantities. You can get delivery immediately. See your Graybar Broadcast Representative about it.

Western Electric

—QUALITY COUNTS—

DISTRIBUTORS: IN THE U.S.A.—Graybar Electric Company. IN CANADA AND NEWFOUNDLAND—Northern Electric Company, Ltd.

Distributed by Graybar — OFFICES IN 92 PRINCIPAL CITIES

Graybar Electric Company, E-34
420 Lexington Ave., New York 17, N. Y.

Please send me complete information on the Western Electric 25B Speech Input Console.

*Name*_____

*Station*_____

*Address*_____

*City*_____ *State*_____

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The Solar System

electronics edition • April 1948

SOLITE* CAPACITORS

IN 600 WVDC RATINGS

LATEST development in SOLITE Metallized Paper Capacitors in the introduction of units with a rating of 600 volts d-c working, 900 volts d-c test.

These capacitors satisfy a growing demand, on the part of designers of compact electronic devices, for higher voltage tubular capacitors with exceptional reliability of performance. SOLITE Capacitors are unequalled for such applications because of their self-healing characteristics.

Type SL cardboard-encased units and type XTILWO insulated section, metal-encased hermetically sealed capacitors are now listed as standard in a wide range of capacitances. Both basic designs are impregnated with mineral wax for stability of electrical characteristics.

Catalog Number	Mf	WVDC	Diam. x Length
TYPE SL CARDBOARD TUBULARS			
SL-6-01	.01	600	3/16 x 5/8
SL-6-02	.02	600	3/16 x 5/8
SL-6-03	.03	600	15/32 x 5/8
SL-6-05	.05	600	15/32 x 5/8
SL-6-1	.1	600	15/32 x 1 1/8
SL-6-2	.2	600	5/16 x 1 1/8
SL-6-25	.25	600	5/8 x 1 1/8
SL-6-5	.5	600	23/32 x 1 7/8
SL-6-1M	1.0	600	23/32 x 2 1/8
TYPE XTILWO METAL TUBULARS			
XTILWO-6-.02	.02	600	7/16 x 2 9/32
XTILWO-6-.03	.03	600	7/16 x 2 9/32
XTILWO-6-.05	.05	600	1/2 x 2 9/32
XTILWO-6-.1	.1	600	1/2 x 1 13/32
XTILWO-6-.2	.2	600	.670 x 1 13/32
XTILWO-6-.25	.25	600	.670 x 1 13/32
XTILWO-6-.5	.5	600	.670 x 1 29/32
XTILWO-6-1	1.0	600	3/4 x 2 13/32
XTILWO-6-2	2.0	600	1 1/8 x 2 13/32
XTILWO-6-3	3.0	600	1 1/4 x 2 13/32

Capacity Tolerance: —20, +30%, unless otherwise specified.

All dimensions in inches.

For grounded section, metal-encased units, specify Type XTGLWO and deduct 3/32" from length.

For plastic or cardboard outer sleeving on metal-encased units, substitute "V" or "P", respectively, for "O" in type designation and add 1/16" to diameter and 1/8" to length.

★Trade Mark

4148

SOLAR "QUALITY ABOVE ALL"

SOLAR MANUFACTURING CORPORATION

1445 HUDSON BLVD. NORTH BERGEN, N. J.

BUSINESS BRIEFS

By W. W. MacDONALD

Checking Up on nine New York newspapers we note that seven print quite complete a-m broadcast programs and two skimp only with respect to number of stations covered. All nine carry full television schedules. One even runs shortwave programs.

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Herald-Tribune	sketchy coverage
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Mirror	lists one station
News	nothing
PM	nothing
Post	nothing
Sun	nothing
Times	adequate coverage
World-Telegram	adequate coverage

RCA's Shorty Engstrom has an explanation of why some listeners think f-m broadcasting is important and some don't that appeals to us. He says the service may be likened to a new delivery boy, and while there are people who value his efficiency others are more interested in what comes in the package.

I've Found The Best Spot for a folded-doublet f-m antenna in my apartment-house living room. Hang it up in the mathematical center of the cubicle, midway between floor and ceiling, and stations roll in just about as well as if the super would let me put the thing on the roof.

There is only one thing wrong about putting the antenna there. My wife won't let me.

Radio-Station Licenses assigned to various types of communications systems in the United States break down as follows:

Police	3,259
Taxi, Bus, Truck	972
Public Utilities	911
Forestry	315
Railroads	92
Geophysical	70
Industrial	62
Limited Common Carrier	60
Highway	52
Fire	49
Petroleum Pipe Line	32

Communications was the safest of 40 major industries surveyed by the National Safety Council in 1947. Workers in this field sustained only 3.33 disabling injuries per 100,000,000 man hours, as compared with 14.16 for all industries studied.

C-R Tube Makers are agitating for fewer types and one kind of deflection. Some think three sizes will do the job, two for direct viewing and one for projection, while others favor five types in all. Magnetic deflection appears to be the favorite.

Object of this incipient campaign among set makers is the substantial reduction in c-r tube costs that could be achieved by reduction of types and resultant mass production.

Larger Pictures are on their way but this does not necessarily mean that projection systems will monopolize the spotlight. Several laboratories are working on cathode-ray tubes having larger screens. If these can be turned out cheap enough, and stubby enough, they may give projection systems a run for their money.

Stancor's Jerry Kahn says the dollar value of component parts in today's average television receiver is ten times that of the parts in a small radio, four times that of a medium radio and twice that of a large combination model.

Compulsory Installation of stall-warning devices on all private airplanes has been recommended to the CAA by a group of aviation psychologists. Tests show that not only student and private pilots, but even flight instructors, consistently fail to detect pre-stall conditions in light aircraft.

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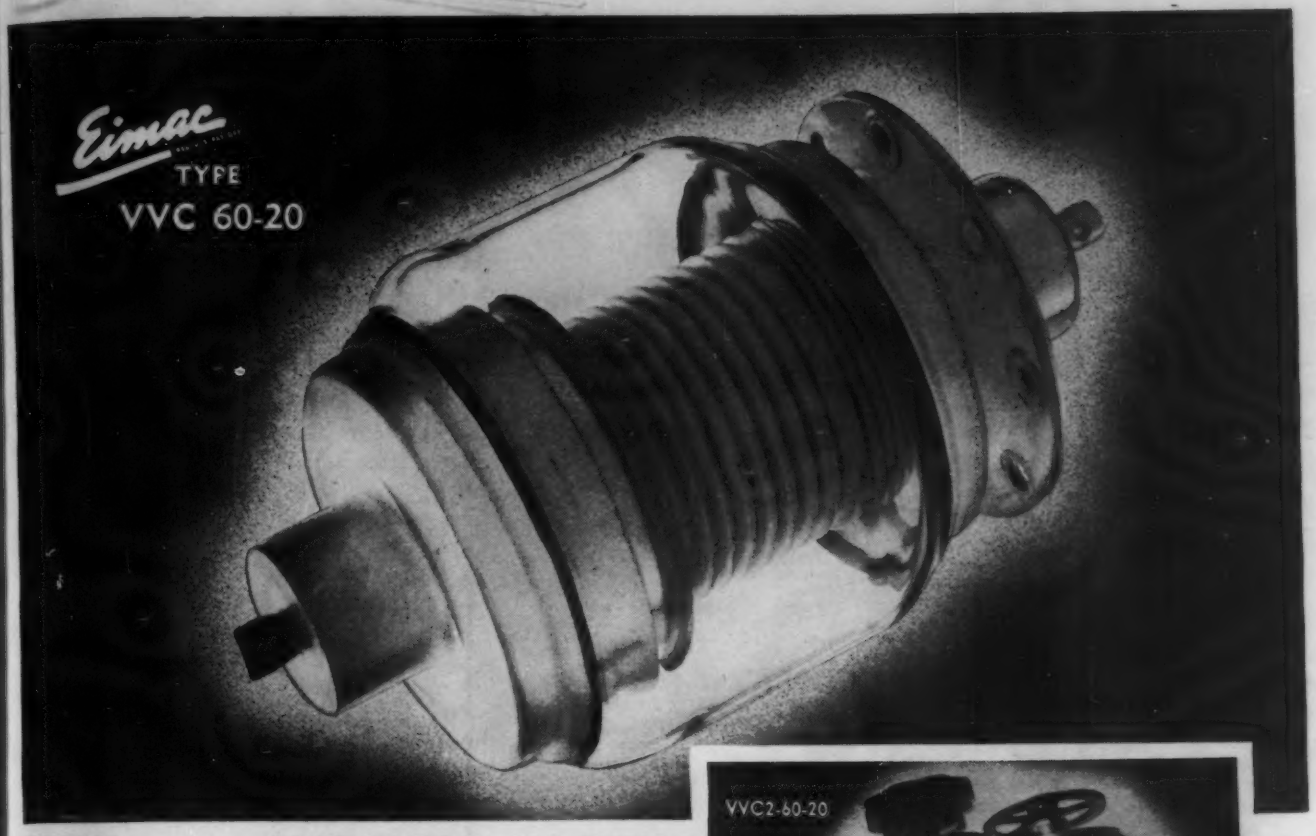


NOW . . . VARIABLE VACUUM CAPACITORS . . . by EIMAC

Here at last is a dependable variable vacuum capacitor that is physically designed for practical application. Every detail of construction makes the Eimac VVC series the standout variable vacuum capacitor component for your equipment. Here is supreme performance and dependability as only Eimac research and engineering can provide.

CHECK THESE FEATURES

PRACTICAL MOUNTING . . . designed for wide application, the base plate on the single units mounts on panel for direct control, or vertically on chasis for control from a flexible shaft or angular control. Multiple units are conveniently bracketed for chassis and panel installation

COMPACT SIZE . . . the single unit VVC-60 is but 3 inches in diameter and 5 inches in length. Multiple units are proportionally larger.

COPPER COMPONENTS . . . for increased R-F conductivity and minimum internal losses. All contact surfaces are silver plated.

MECHANICALLY RUGGED . . . bellows, bearings and adjusting mechanism designed to withstand excessive use and provide long life.

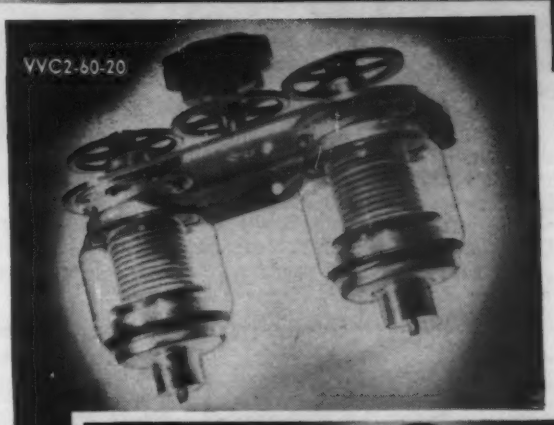
SIMPLE CONTROL . . . single and multiple units vary capacitance by rotation of a single knob. Return to previously indexed settings is positive.

For further information see your Eimac dealer or write direct.

EITEL-McCULLOUGH, INC.
194 San Mateo Avenue, San Bruno, California

EXPORT AGENTS: Frazar & Hansen—301 Clay St.—San Francisco, Calif.

Follow the Leaders to
Eimac TUBES
The Power for R-F



GENERAL CHARACTERISTICS

	Capacity	R-F Peak Voltage	Maximum RMS Current
VVC 60-20	10-60 mmf.	20-KV	40 amp.
VVC2-60-20			
Parallel	20-120 mmf.	20-KV	80 amp.
Split-stator	5-30 mmf.	40-KV	40 amp.
VVC4-60-20			
Parallel	40-240 mmf.	20-KV	160 amp.
Split-stator	10-60 mmf.	40-KV	80 amp.

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The Solar System
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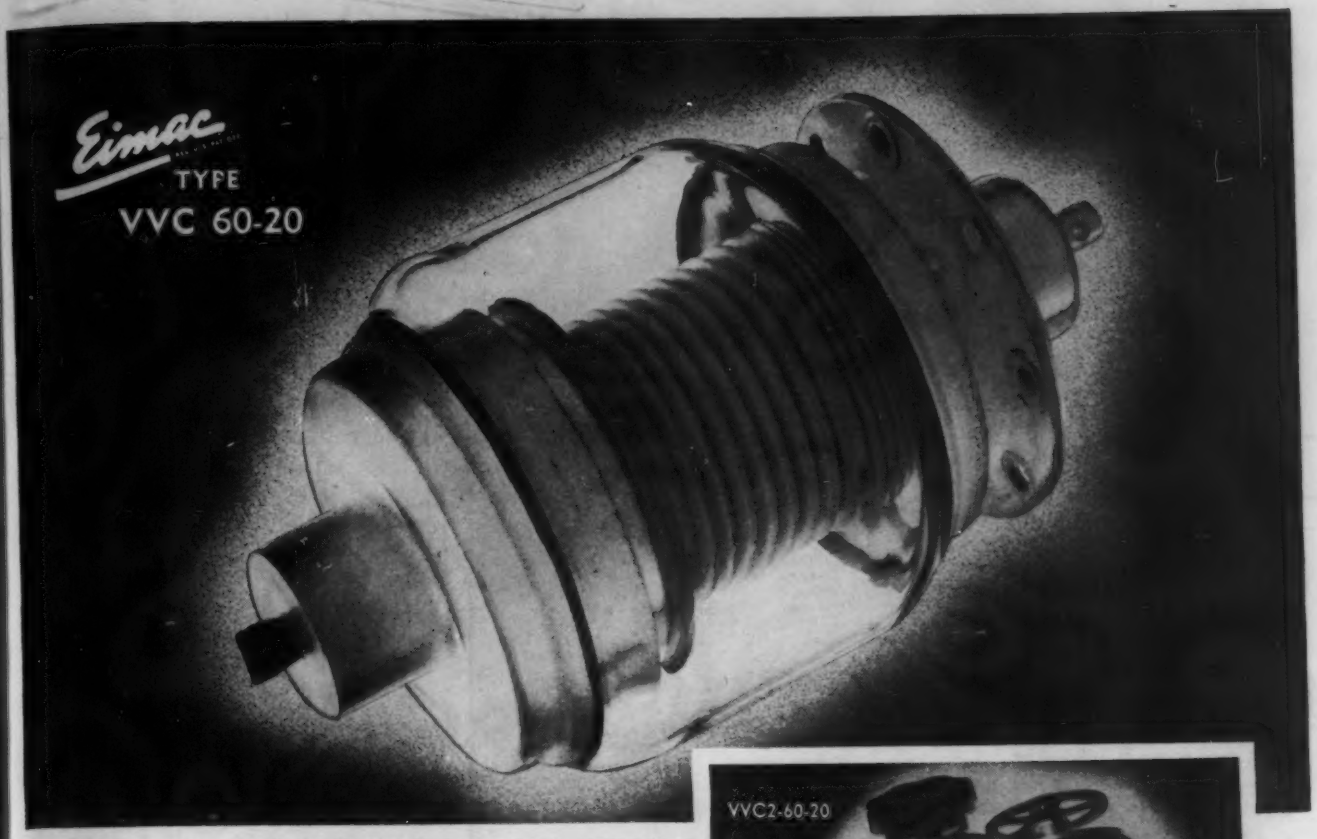

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EITEL-McCULLOUGH, INC.
194 San Mateo Avenue, San Bruno, California

EXPORT AGENTS: Frazar & Hansen—301 Clay St.—San Francisco, Calif.

Follow the Leaders to
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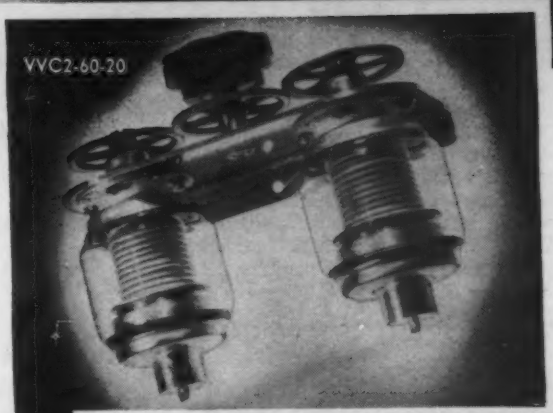
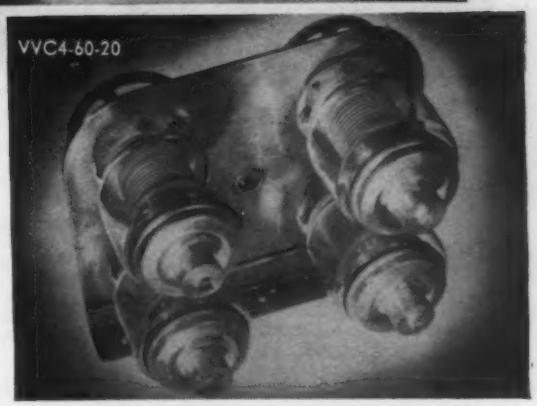
TUBES
The Power for R-F





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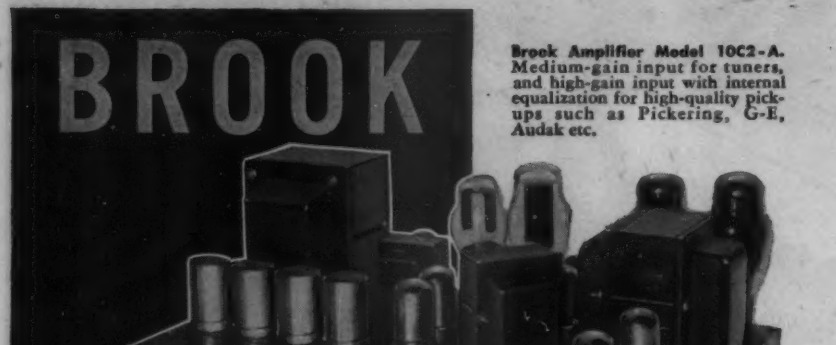


Brook Amplifier Model 10C2-A. Medium-gain input for tuners, and high-gain input with internal equalization for high-quality pick-ups such as Pickering, G-E, Audak etc.

An Amplifier Which Gives New Meaning To High Quality Audio Reproduction

So outstanding is the Brook All-Triode Amplifier that new engineering and listening standards must be applied to evaluate its remarkable performance.

From an *engineering* standpoint, it is notable in the fact that distortion has been reduced to the vanishing point . . . far lower than in any amplifier using pentodes or beam-power tubes. From a *listening* standpoint, it is notable because of its ability to reproduce fine music with a degree of fidelity never before achieved outside the laboratory.

No matter what the basis for comparison, the performance of the Brook Amplifier is unparalleled. Hear one at your earliest opportunity.

Full technical description will be mailed without obligation. *Write today for Bulletin BD-8!*

SPECIFICATIONS

★ Frequency response flat within *two-tenths* DB from 20 to 20,000 cycles.

★ Both intermodulation and harmonic distortion reduced to negligibility (Exact figures shown in technical sheet).

★ Rated output 30 watts.

★ Bass and treble compensation—two-stage R-C network. Bass boost as much as 13 DB without boominess.

★ Gain—55 to 120 DB in various models.

★ Impedances — Input, 0.5 megohm standard, others available. Output, 1.5 to 30 ohms, with separate 500-ohm winding.

EXCLUSIVE BROOK FEATURES

TRIODES THROUGHOUT! It is a well known fact among experienced audio engineers that triodes of low amplification factor are essential if minimum distortion is to be obtained. Although their use is costly compared with pentodes, triodes are used *in all stages* of the Brook Amplifier.

SPECIAL TRANSFORMERS. Transformers used in all Brook models are completely free from saturation or leakage reactance effects from 25 to 20,000 cycles at any power up to maximum. They are manufactured to our specifications, and are available in no other amplifier.

AUTOMATIC BIAS CONTROL. ABC is a Brook-patented circuit feature which more than doubles the power output and efficiency of the output system, and at the same time reduces harmonic distortion. It is a principle factor in achieving the remarkably low distortion which is characteristic of the Brook Amplifier.

DEALERS — CUSTOM BUILDERS

If you serve a quality conscious clientele, you can add to your profits and prestige with the Brook All-Triode Amplifier. Normal discounts apply. Inquire.

The BROOK HIGH QUALITY AUDIO AMPLIFIER

BROOK

Designed by LINCOLN WALSH

BROOK ELECTRONICS, Inc., 34 DeHart Place, Elizabeth 2, N. J.

comparison between waveform of the original sound and that heard by the pig. The effect of various drugs on the nervous system may thus be tested.

Watching some experiments in Rahway we noted that if one talked at a pig so wired for sound he made a pretty good microphone.

Vernier-Scale Dial designed by a subscriber out in Ohio facilitates accurate readings by passing light from a back-of-panel lamp through small holes or slots used in lieu of or in addition to the usual graduation marks. The scheme seems particularly adaptable to high-class instruments, and should have considerable eye appeal. Name and address on request to anyone interested in manufacturing rights.

Office of Naval Research financial obligations contracted during the fiscal year ending June 30, 1947 totalled $59,200,000. This was broken down as follows:

Research Division	$28,500,000
Naval Research Lab.	17,500,000
Special Devices Center	11,700,000
Administration	1,500,000

ONR personnel, officers, enlisted men and civilians, totalled 4,117 broken down as follows:

Naval Research Lab.	3,232
Office of Naval Research	286
Special Devices Center	405
U. S. Branch Offices	136
Underwater Sound Ref. Lab.	38
London Branch Office	20

Estimates for 1948 are not yet available.

Hotel Survey among operators of 5,700 buildings indicates that $6,850,000 is being spent, or will be spent in the next few months, for radio and television equipment. C. A. Horrworth of the American Hotel Association is the authority.

Even Our Expert Draftsmen make mistakes once in awhile. We had to reletter the circuit of an electronic organ the other day before making a cut because it contained the words *soft-shell crab.* It should have read *soft-swell tab.*

Smart Merchandising Trick used by Hermon Hosmer Scott involves sending a special test record along

with every broadcast-station model Dynamic Noise Suppressor (ELECTRONICS, p 96, Dec. 1947) sold. The purchaser is told in an instruction sheet how to adjust the controls for best results, using the record as a standard signal source.

Here's an idea readily applicable to other electronic apparatus commonly misused by new customers.

Facsimile Broadcasting is underging test by newspapers in Miami, Philadelphia, and New York owning f-m stations. Initial programs feature stock-market reports and news of primary interest to business executives. Orders for experimental transmitting and receiving equipment have also been placed with several facsimile manufacturers by newspapers in Akron, Atlanta, Baltimore, Des Moines, Hartford, New Bedford (Mass.) and St. Louis.

Receiving-Tube Sales by RMA members totalled 199,533,827 in 1947, as against 205,217,174 in 1946. New equipment used 131,-986,468 tubes, replacement 43,-530,058, export 23,184,172 and government agencies 833,129.

Taken For Granted is the importance of radio aboard ships at sea, so much so that little has been written about marine gear in recent years. Oldtimers in particular will be interested in a yarn on the subject now being readied for publication in ELECTRONICS.

Also In Preparation is a description of special transmitting and receiving antennas for the Citizens' Radio Service, part of our article series on the subject. And a wad of fundamental data about electronic calculators.

Johns-Manville Lab over in New Jersey is equipped with four color-coded pipelines that carry air, vacuum, gas and water to every experimental bench. Visiting there recently, we noted that some wag had chalked on one of his spigots the words *Birch-Beer.*

Definition: A *project* is work that takes twice as many men twice as long to complete as a *job.*

"They used to call me 'THE CREEP'..."

". . . but that was before the boss discovered there was a *difference* in tracing cloths. Ink just can't help creeping and feathering when you use a French curve, if the tracing cloth has a poor surface."

Arkwright gives you the kind of surface that practically assures razor-sharp lines. Oil, wax and soap-free mechanical processing assures uniform capillarity. Even the weaving and bleaching of special cloth is part of Arkwright's exhaustive system of standards, tests and inspections—to *prevent* pinholes, thick threads and the many other things that cause spoiled tracings, lost time.

Why not try Arkwright and see for yourself what a difference there is? Send for free working samples. Arkwright Finishing Company, Providence, R. I.

All Arkwright Tracing Cloths have these 6 important advantages

1 *Erasures re-ink without "feathering" or "creeping".*
2 *Prints are always sharp and clean*
3 *Tracings never discolor or become brittle*
4 *No surface oils, soaps or waxes to dry out*
5 *No pinholes or thick threads*
6 *Mechanical processing creates permanent transparency*

Arkwright
TRACING CLOTHS
AMERICA'S STANDARD FOR OVER 25 YEARS

Operating Room Gauze Is Not Pure Enough For This MALLORY CAPACITOR!

The chloride content of the gauze used in making Mallory FP Capacitors is *less than one-half of one part per million!* To accomplish this, Mallory demands more thorough purification than is required for the gauze used in hospitals!

Purity for Longer Shelf-Life

Due principally to this precaution, Mallory FP Capacitors stubbornly resist deterioration on the shelf or in storage. Cases are on record where Mallory Capacitors have proved ready for use without re-aging after more than *six years* in storage.

Useful in Television and FM Sets

FP Capacitors are ideal for vertical mounting and contain the famous Mallory "Fabricated Plate" anodes. They give equivalent capacity and voltage in less space. Their pure internal construction and tightly sealed cases make them ideal for tropical use.

Buy Mallory Assured Quality at Regular Price Levels

Yours for the asking!

Send for the Mallory Capacitor Catalog, which contains useful data on all types of Mallory Capacitors—sizes, electrical characteristics, test measurements, mounting hardware.

P. R. MALLORY & CO. Inc.

MALLORY CAPACITORS

(ELECTROLYTIC, OIL and WAX)

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

James H. McGraw, Sr.
1860 - 1948

JAMES H. MCGRAW, SR., founder of the McGraw-Hill Publishing Company, for many years its guiding light and an outstanding figure in the publishing world, died at the age of 88 on February 21 in San Francisco.

Mr. McGraw was a distinguished product of our system of free enterprise, of the era when strong men single-handedly and on shoestrings founded strong enterprises. Starting out in life as a normal-school principal, he exchanged this career for one in the publishing world 64 years ago, selling subscriptions to *The American Journal of Railway Appliances*. When, at the end of two years, his employers owed him $1,500 he borrowed money to bolster the company, becoming a vice-president.

WHEN THOMAS A. EDISON'S electric car was demonstrated Mr. McGraw left his partners and founded his own paper, *Street Railway Journal*. By 1901 he had become so sure electricity was here to stay that he acquired *Electrical World*. Soon he added *Engineering Record* and *Chemical and Metallurgical Engineering*. Out of his experience in the electrical field came *Radio Retailing* and, later, ELECTRONICS.

In 1916 the Hill publications, *Power, American Machinist, Coal Age, Engineering and Mining Journal* and *Engineering News*, were acquired. The McGraw-Hill organization expanded in the national scene, with many business and engineering periodicals. Continuing to grow, the company today publishes 26 national and eight international magazines. Moreover, the book departments of the McGraw and Hill companies, merged in 1909 to form the McGraw-Hill Book Company, constitute the largest technical book publishing house in the world.

MR. MCGRAW'S ATTITUDE toward the technical publishing field in general and toward his own papers in particular was always interesting and inspiring. He was the first in this field to publish accurate figures showing the circulation of his papers; he was a firm believer that his properties had to be leading papers in the areas in which they operated, that his editors had to be experts in those areas, that the first job of any technical journal was to perform a truly valuable editorial service.

His success can, perhaps, be laid primarily to his firm belief in individual initiative, in imaginative publishing, in editorial integrity, and to a supreme dissatisfaction with present effort,, no matter how good it might be at the moment. Publishing leadership, in his opinion, was built upon an intimate knowledge of the field.

MR. MCGRAW'S IDEALS were passed on to his four sons; James H. McGraw, Jr., now president and chairman of the Board; Harold W. McGraw, vice-president in charge of the McGraw-Hill Building in New York; Curtis W. McGraw, senior vice-president and treasurer; and Donald C. McGraw, vice-president in charge of manufacturing.

Under their guidance the staff carries on Mr. McGraw's traditions.

Photo of test pattern on 12 x 16-inch screen of television receiver using new projection box, showing 325-line horizontal resolution, 350-line vertical resolution, geometric properties and reproduction of gradations from white to black

By H. G. BOYLE
and
E. B. DOLL

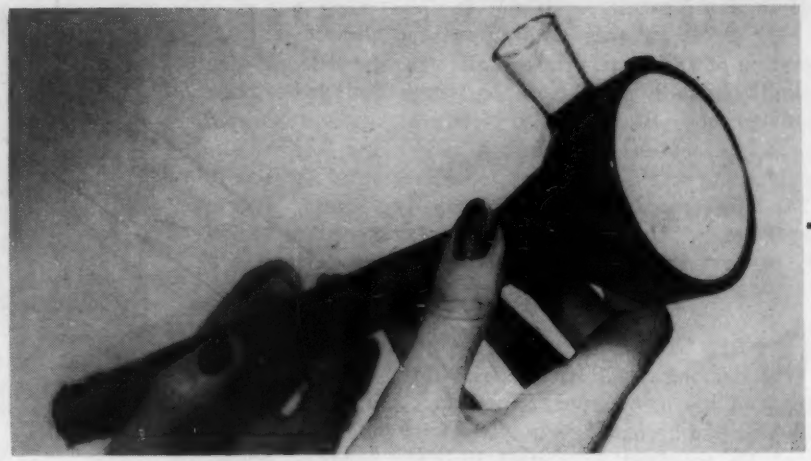
North American Philips Co., Inc.
New York and Dobbs Ferry, N. Y.

Compact PROJECTION

POSTWAR commercial television experience has emphasized the desirability of larger pictures than can at present be produced by direct-viewing tubes of convenient size.

The alternative method of producing a large television picture by optical projection of the picture formed on a small cathode-ray tube has always held interesting possibilities. However, enough light must be projected from the tube face to yield a satisfactory viewing-screen brightness. This sets certain limitations on the minimum practicable tube size and, at the same time, demands a large-aperture optical system to utilize efficiently the available light. Heretofore, such projection systems have not greatly reduced the space required below that necessary for large direct-viewing tubes, although somewhat more freedom is allowed in the disposition of that space.

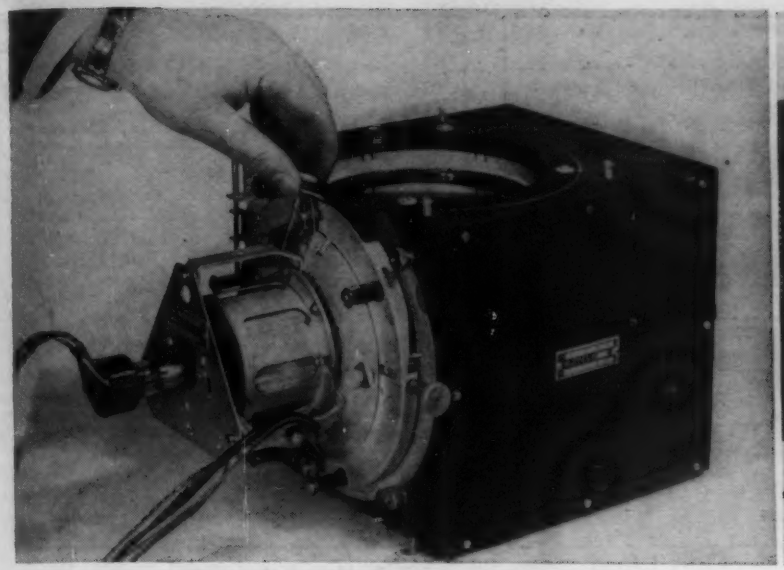
In order to obtain a sufficiently bright, well defined, enlarged picture from a small cathode-ray tube, an acceleration voltage considerably in excess of that used for direct-viewing tubes is required. The generation of this high voltage presents engineering and manufacturing problems which partially reduce the potential economies of the projection method. In many cases the ultimate picture quality will depend to a large degree upon the characteristics of the high-voltage supply. In addition, the energy required to deflect the high-velocity electron beam generally involves the use of additional circuit components.



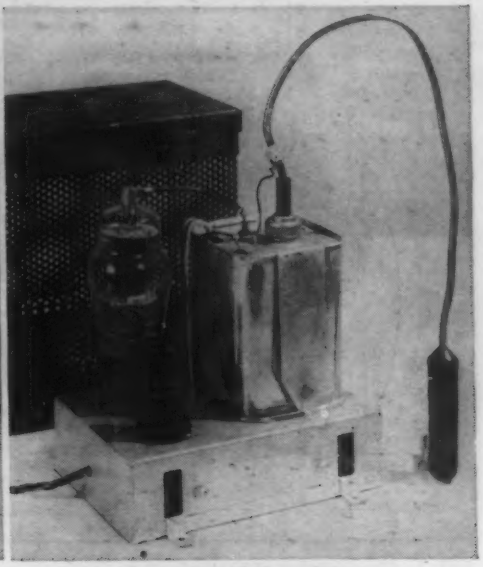
Special 2.5-inch diameter c-r tube developed for use in projection box

Further development of a projection television system described elsewhere[1] has resulted in a compact and efficient system known as Protelgram, in which the potential advantages of the projection method are realized to a greater extent than has heretofore been practicable. The system consists of: (1) a 2.5-inch projection tube; (2) an optical projection unit, including deflection and focus coils; (3) a 25-kilovolt high-voltage supply. A large television picture, 12 x 16 inches, is produced with satisfactory brightness, contrast, and resolution.

This integrated system is so designed that circuit requirements may be satisfied by a 10-inch television receiver chassis, such as is



Complete projection box, showing method of adjusting focus



Pulse-type 25,000 volt power supply

TELEVISION SYSTEM

Triangular arrangement of Schmidt optical system permits design of compact projection box using 2.5-inch cathode-ray tube and giving 12 x 16-inch picture. Corrector lens is made from gelatin sealed between glass plates. Pulse-type 25-kv voltage-tripling power supply uses special control circuit to improve regulation

used with a type 10BP4 cathode-ray tube.

Projection Tube

A small projection cathode-ray tube leads to a substantial saving in the cost and size of the optical components necessary in the associated projection unit. To obtain satisfactory resolution and brightness for the desired 12 x 16-inch projected picture, a 2.5-inch diameter tube face represents the minimum practicable size. The use of magnetic focus, magnetic deflection with a moderate deflection angle, and an acceleration potential of 25 kilovolts permits the design of an electron gun which produces a 0.003-inch diameter spot at the tube face. This spot permits adequate resolution of the 1.4 × 1.86-inch, 525-line television image formed on the tube face. The 2.5-inch tube face also provides sufficient illumination for the 12 × 16-inch projected picture.

The projection tube has an overall length of 10.5 inches, and a neck outside diameter of 0.875 inch. Because of the narrow neck and the moderate deflection angle of only 40 degrees, the deflection sensitivity is comparable to that of a magnetic direct-viewing tube (10BP4) operating at 9 kilovolts, even though the acceleration potential is 25 kilovolts.

The triode magnetic gun results in a simple though necessarily precise assembly which is selfsupporting within the narrow glass neck. A unique internal shield equalizes the potential distribution within the tube, permitting the use of a high acceleration potential in a small envelope without difficulties due to internal flash-over or spot distortions due to accumulated electrostatic wall charges.

The tube face plate, on which the phosphor screen is deposited, must be an accurately defined spherical surface to meet the requirements of the Schmidt optical system with which the tube is used. The face plate is formed by a precise molding process which requires no later grinding or polishing operations. After the face plate is sealed to the cone of the tube the fluorescent screen is applied and aluminized. The metal-backed screen eliminates the need for an ion trap. Aluminizing also increases both brightness and contrast, in addition to providing a more stable picture due to the greater electrical conductivity of the aluminized screen. A blend of several phosphor powders is used to produce light having a color temperature of about 6,200 degrees Kelvin, representing a visually pleasing shade of white. The color is independent

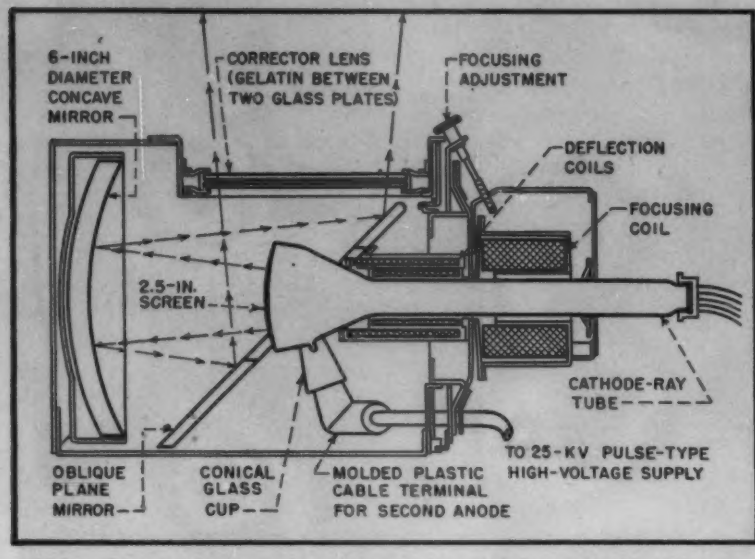


FIG. 1—Cross-section of projection box, showing optical triangle formed by concave mirror, corrector lens, and plane mirror

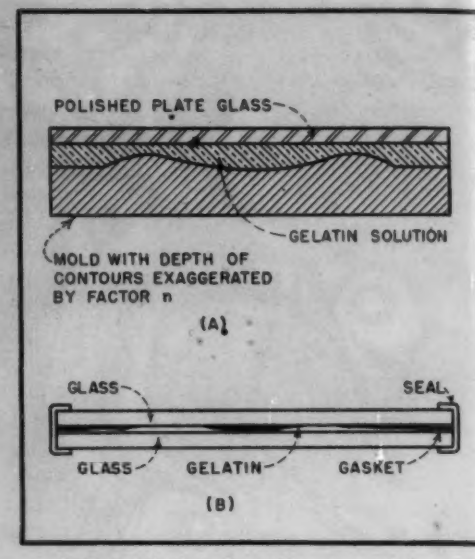


FIG. 2—Method of molding corrector lens from gelatin

of focus conditions or highlight brightness, a desirable characteristic in any cathode-ray tube used for television.

Bombardment of the face plate by the 25-kilovolt electron beam produces soft x-rays which are well absorbed by the projection box. However, objectionable discoloration of the face plate is produced in time if it is made of one of the glasses normally used for cathode-ray tube construction. A special glass is used for the face plate to reduce the x-ray discoloration to negligible proportions.

The high-voltage connection is recessed in a conical glass cup which materially increases the leakage paths, and no corona or flashovers occur when a close-fitting molded plastic high-voltage cable terminal is used. The outer walls of the tube neck and cone are maintained at ground potential by means of an Aquadag coating and ground clips. This shield and the aluminum film on the internal surface of the tube form an approximately 300-$\mu\mu$f capacitance that serves as the final filter capacitor for the high-voltage supply.

Under normal picture conditions, the average beam current is 90 microamperes, with highlight peaks of more than 500 microamperes. The highlight brightness of the 1.4 × 1.86-inch picture is about 3,000 foot-lamberts, which in conjunction with the wide-aperture optical system and a suitable viewing screen gives a satisfactory projected picture brightness.

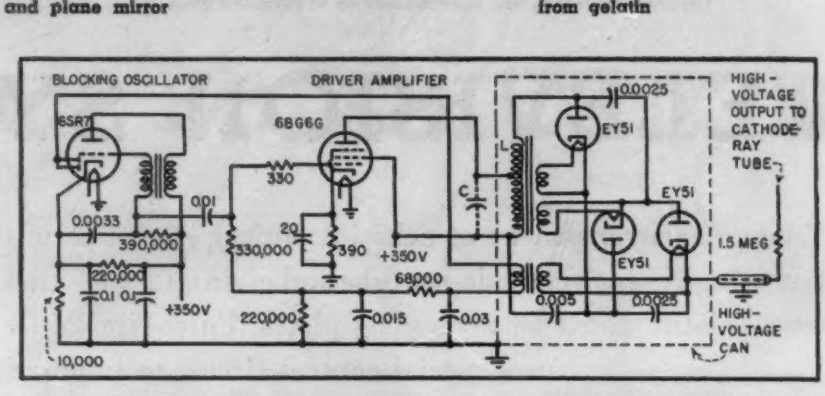


FIG. 3—Circuit of pulse-type voltage-tripling power supply providing 25,000 volts d-c for second anode of cathode-ray tube

Projection Box

A linear optical magnification of 8.6 is required to produce the 12 × 16-inch picture projected from the small image formed on the tube face. To obtain an efficient, compact optical unit of moderate cost, a modified version of the well-known Schmidt optical system is employed. The optical elements of the modified Schmidt system, mounted in a triangular array, constitute one portion of the projection box. The remainder of the box consists of a removable mounting and alignment assembly which supports the projection tube, deflection yoke, and focus coil. This also provides means for adjustment of tube position to obtain a correctly focused projected picture.

In any projection system utilizing reflective optics a certain amount of light is intercepted by the light source. When using a small cathode-ray tube the necessary accessories, such as deflection yoke, focus coil, and mounting supports, are likely to have a larger cross-section than the tube face, thus making it desirable to use an arrangement in which these accessories are removed from the light path. The solution adopted involves the addition of an oblique plane mirror between the corrector lens and the concave mirror so that the optical path is folded, as shown in Fig. 1. This assembly of concave mirror, plane mirror, and corrector lens forms the optical triangle referred to above. The tube face protrudes through an elliptical hole in the plane mirror. The masking factor is reduced to practically that of the tube face alone since the accessories are located behind the plane mirror, outside the optical path. In addition, this

arrangement permits a compact optical unit which is unusually adaptable to a variety of receiver cabinet designs.

The small tube face permits a wide-aperture optical system to be realized by the use of relatively small components. The concave mirror is only 6 inches in diameter and has a focal length of 4 inches, while the corrector lens has a diameter of 4.5 inches. The numerical aperture (sine of the half-angle subtended by the concave mirror at the center of the tube face) of the system is 0.62, and the overall optical efficiency is 15 percent after allowing for masking, reflection, and transmission losses. The required linear magnification of 8.6 is obtained at a projection throw of 31 inches from the corrector lens.

Since no hole is required at the center of the corrector lens, a simple and convenient means is available for adjusting it to its correct position at the reflected center of curvature of the concave mirror. A small V is molded at the center of the corrector lens. The adjustment is correct when the tip of the V coincides with that of the reflected image from the concave mirror. It is not necessary to remove the corrector lens for picture-tube replacement, and the precise adjustment of the optical triangle can be permanently fixed at the factory.

The aspherical corrector lens is manufactured by an interesting and simple process. A mold is prepared to the exact radial dimensions of the desired aspherical contour but with the depth of contour exaggerated by some chosen factor, n. A piece of polished plate glass is placed over the mold and the combination is heated, after which a $100/n$ percent solution of gelatin in water is injected between the mold and the glass, as indicated in Fig. 2A. Upon cooling, the gelatin solution solidifies and adheres to the glass plate when removed from the mold. When the water evaporates, the layer of gelatin shrinks only perpendicular to the surface of the glass, since the strong adhesion prevents any tangential shrinkage.

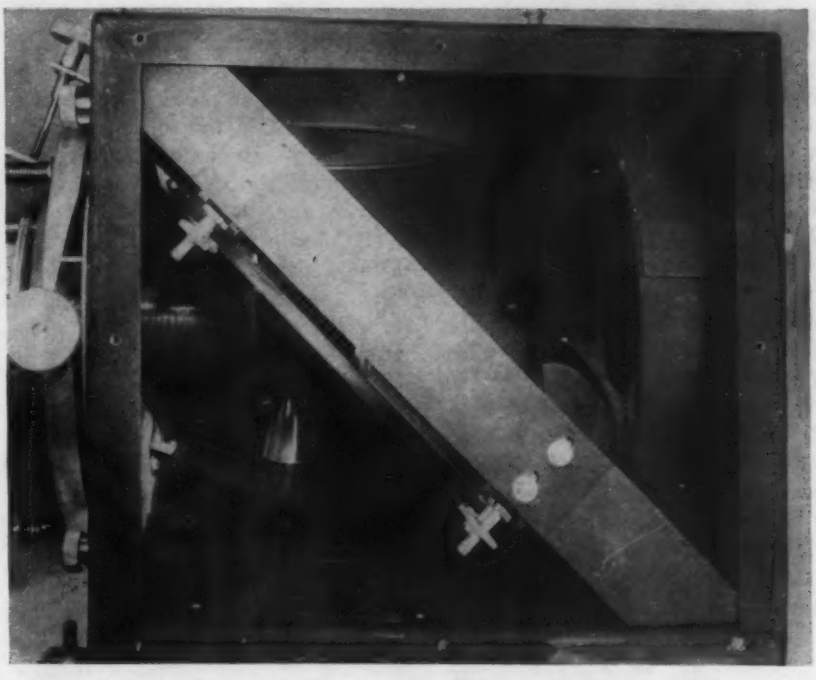
After drying, the glass plate is left with a hard gelatin layer the surface of which is an n-fold reduction of the original mold, and therefore has the desired aspherical corrector lens contour. The plate is then sealed to a second glass plate, as shown in Fig. 2B, giving a finished corrector lens which will withstand all normal handling encountered in mounting and cleaning.

It is readily seen that the expanded mold scale makes the mold much easier to construct to the required accuracy and finish when n has a value considerably greater than unity. An additional advantage is derived from the fact that a change in initial gelatin solution concentration permits the preparation of corrector lenses of different strengths from a single mold in case it is desired to change the optical magnification of an existing Schmidt system.

The mounting and alignment assembly of the projection box includes the deflection yoke and focus coil. The conical section of the tube seats firmly in the molded phenolic deflection yoke form, and the tube is anchored by a clamp near the tube base. Means are provided for tilting the focus coil with respect to the tube axis to serve as a centering control, or to adjust for optimum spot resolution on the tube face if other means of centering are employed. Because of the small tube neck and the particular mounting arrangement, a special deflection yoke and focus coil are used. These items have been designed to be identical, in electrical characteristics and power sensitivity, to the conventional units used for direct-viewing tubes.

Since the Schmidt optical system has a very short depth of focus, the spherical tube face must be precisely located within the fixed optical triangle to obtain satisfactory resolution on the viewing screen. To compensate for the normal dimensional tolerances involved in the manufacture of both the projection box and the tube, means are provided on the mounting and alignment assembly to accurately adjust the tube face to its required position. A spherical cap permits small rotational movements about the nominal center of the tube face, thus causing no motion of the projected picture on the viewing screen during adjustment. Thumbscrew adjustments provide movement over the spherical surface in addition to a longitudinal movement which serves as the principal optical focus control.

After the tube is mounted and the high-voltage cable connected, the alignment and assembly head



Interior of projection box, showing c-r tube at left, concave mirror at right, corrector lens at top, and plane mirror mounted on 45-degree slant

is secured to the fixed optical triangle by additional thumbscrews. The assembled projection unit is dustproof, which assures long life of the front-surface mirrors. The controls described above permit rapid and precise adjustment of the final projected picture to sharp optical focus, using the television image on the tube face as the light source. This adjustment is required only when the cathode-ray tube is replaced. The projection box optics are capable of 1,000-line resolution (television terminology) which is more than adequate for the projection of a 525-line television image.

High-Voltage Unit

The general applicability and performance of a projection television system depends to a large degree upon the electrical and physical characteristics of the high-voltage supply. Desirable characteristics include good regulation, small size, versatile mounting possibilities, low input power requirement, and freedom from corona and other difficulties over a wide range of ambient temperature and relative humidity conditions.

Good output voltage regulation is necessary to assure a stable picture of high resolution, since the normal variations in picture content cause the average beam current of the projection cathode-ray tube to vary between rather wide limits. In many cases the ultimate projected picture quality and size stability are determined primarily by the effective internal resistance of the high-voltage supply.

The high-voltage unit of this projection system satisfies these requirements and has a remarkably good load voltage regulation characteristic which materially increases the quality of the projected picture. In addition, this high-voltage supply causes no radiation interference with its associated television receiver or with adjacent television and radio receivers.

A pulse-type high-voltage power supply is used as indicated in Fig. 3. The triode section of the 6SR7 tube operates as a conventional blocking oscillator, and generates a sawtooth voltage which is applied to the control grid of the 6BG6G driver tube. Since the driver tube is biased beyond cutoff, its plate current flows in sawtooth pulses corresponding to the peaks of the input grid signal. Assuming that the plate load inductance L is shunted by a stray capacitance C, the peak voltage E_m of the transient oscillation caused by the periodic interruptions of peak plate current I_m may be deduced from the expression $0.5\ LI_m^2 = 0.5\ CE_m^2$, which equates the energy stored in the inductance at the moment of interruption to the energy stored in the shunt capacitance at the first peak of the transient oscillation. This leads to $E_m = I_m \sqrt{L/C}$ for the peak voltage value.

By tapping the plate of the driver tube down on the plate load inductance, the peak output voltage can be increased for a given maximum peak plate potential. However, a practical limitation exists on this step-up ratio, since increasing the inductance also increases the stray capacitance. In this power supply, the plate tap includes approximately 70 percent of the turns on the primary of the high-voltage transformer.

It may be shown that the interruption frequency for a pulse power supply of this type is given by $F_i = \alpha\ (E_s - E_p)/Li_m$, where α is the fraction of the total time during which driver plate current flows, E_s is the plate supply potential, and E_p is the minimum plate voltage required to produce the maximum plate current i_m in the driver tube.

To obtain good input power efficiency, this power supply uses a plate supply of 350 volts and a repetition rate of 1,000 cps. The transient oscillation frequency is 25,000 cps. Although the peak plate current is approximately 175 ma and the average plate current required is about 25 ma under normal operating conditions, a type 6BG6G driver tube is used to withstand the high transient plate voltage peaks.

Because of the practical limitations on the peak voltage ratings of the transformer, the driver tube, and the rectifier tubes, a voltage tripler circuit is used to produce the required 25-kilovolt output voltage. This voltage multiplier is of the cascade type where both the positive and negative peaks of the transient oscillation are used to develop the final high voltage. The small rectifier tubes are of special design, measuring 1.5 inch long x 0.5 inch in diameter and having a peak current rating of 165 ma, with a heater requirement of 0.5 watt.

The rectifier heaters are energized from the high-voltage transformer by extra secondary windings. In order to obtain sufficient heater power for the rectifier diodes at a low total power input, the losses of the resonant circuit have been reduced by using a shell-type core of Ferroxcube III[a], a new ferromagnetic ferrite, for the high-voltage transformer. The use of this core material also permits a very compact transformer.

Power supplies of this type generally have a relatively high internal resistance. In special cases a low internal resistance can be obtained, but this involves operation at very low input efficiency. As was pointed out above, a good load voltage regulation characteristic is necessary to realize the full capabilities of a projection television system.

The internal resistance of this power supply is lowered appreciably by an interesting control circuit. An extra winding is placed on the high-voltage transformer and the voltage induced in this winding is rectified by the diode section of the 6SR7 tube to regulate automatically the control grid bias on the driver tube. The peak plate current of the driver tube may be controlled by adjusting its grid bias, since the amplitude of the driving sawtooth voltage remains constant. By the use of this control circuit, which incorporates a delay bias on the feedback rectifier, an effective internal resistance of 7 megohms is obtained at the output of the voltage multiplier, making possible the performance curves of Fig. 4.

The normal projection tube average beam current required is 90 microamperes, but the high-voltage supply is capable of delivering 150 microamperes with excellent regulation to satisfy the beam-current demand on bright pictures. The highlight peak current demands are

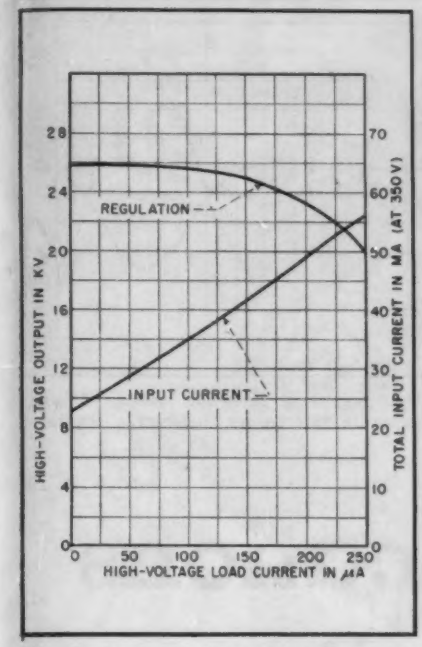


FIG. 4—Power supply performance curves

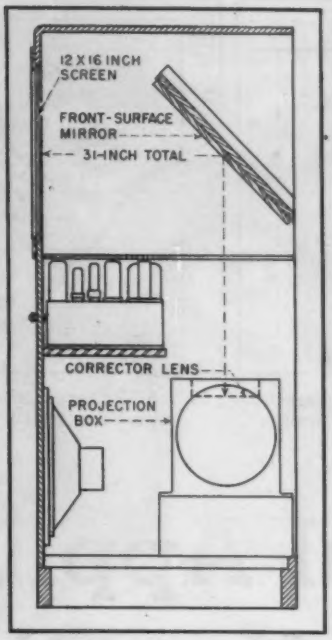


FIG. 5—Suggested cabinet layout

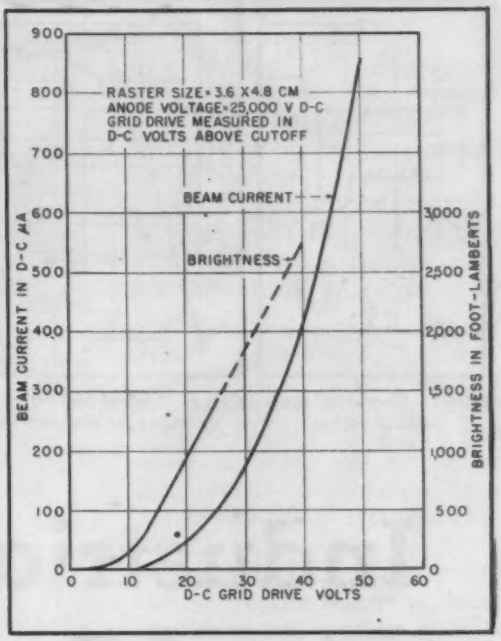


FIG. 6—Beam current and brightness curves

supplied by the output filter capacitors, and the time constant of these capacitors with the effective load resistance is considerably greater than one field period.

A series protective resistor is included in the output of the high-voltage unit to limit transient short- circuit currents, and, in conjunction with the envelope capacitance of the cathode-ray tube, to form the final filter section. Under short-circuit conditions, the output voltage of the unit drops to zero, and no damage is caused by accidental overloads.

To eliminate voltage breakdown and corona difficulties due to the high voltages involved, the high-voltage transformer, the rectifier tubes, and the filter capacitors are assembled in a small metal can and vacuum-impregnated with oil. This construction also yields a remarkably small high-voltage unit. In the event of rectifier tube failure, it is a simple operation to replace this sealed assembly. The completed high-voltage unit, including the blocking oscillator and driver tubes, is mounted on a small chassis and is provided with a cover.

Receiver Considerations

Because of its high efficiency, small size, and integrated design, this projection television system may be readily adapted to existing chassis designs. The projection components may be used in a variety of receiver cabinets, ranging from table model sets to larger consoles, all producing the large 12 x 16-inch picture.

A representative receiver arrangement, using a transmissive screen and a large cabinet mirror, is illustrated in Fig. 5. The packaged projection system reduces the problems of design and manufacture of a projection television receiver to the familiar ones associated with a direct-viewing receiver, since the circuit requirements are substantially identical and the special problems of high voltage and optics are eliminated by the use of completely tested subassemblies.

The performance characteristics of a projection television system are quite dependent upon the type of viewing screens used. A variety of viewing screens has been proposed for projection television. These screens vary from highly diffusing surfaces which give an extended viewing angle at the expense of brightness, to highly directional screens with different vertical and horizontal dispersion characteristics which limit the viewing angle, but which also increase the effective brightness of the reproduced picture. Both transmissive and reflective screens have been used with considerable success. In most cases a square-cornered projected picture is formed on a flat surface, eliminating the rounded corners and linear distortions which are frequently objectionable when pictures are viewed on a curved tube face. The final choice of a viewing screen to be used with a projection television system depends upon the particular application in view, and a variety of screens may be used with this projection system to fulfill various requirements.

This system produces a highly satisfactory picture of optimum size to satisfy the requirements of most viewers. When used with a moderately directional transmissive screen, having controlled vertical and horizontal light distribution characteristics (approximately ± 12 degrees vertically and ±30 degrees horizontally, with a brightness gain of about 7), a highlight brightness of 45 or more foot-lamberts is obtained with a cathode-ray tube having the characteristics shown in Fig. 6. With this type of screen, giving a contrast ratio of 30 to 1, 450-line resolution is achieved.

References

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(2) J. L. Snoek, Nonmetallic Magnetic Material for High Frequencies, *Philips Technical Review*, p 353, Dec. 1946.

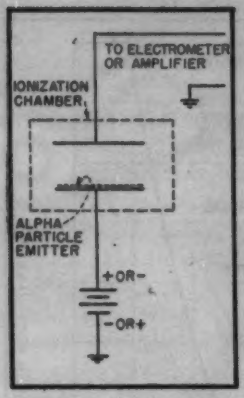


FIG. 1—Elemental ionization chamber

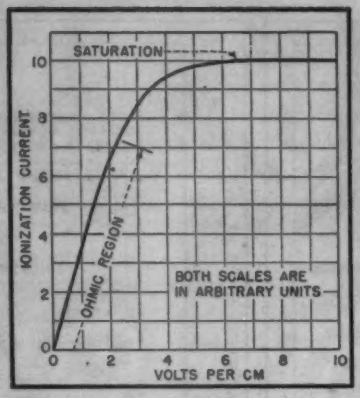


FIG. 2—Typical ionization characteristic curve of radioactive resistor

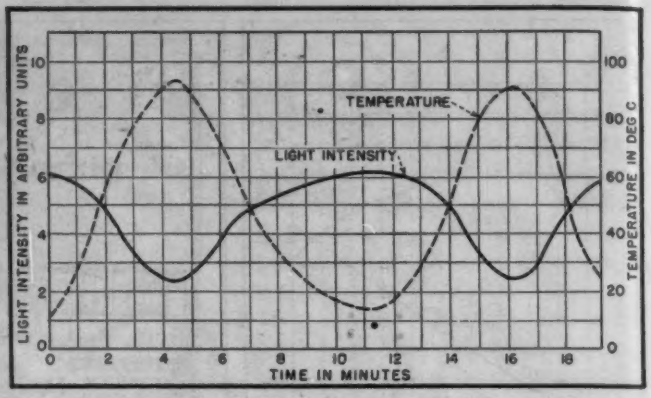


FIG. 3—Variation in light output of luminous compound with temperature during exposure to constant radioactive source

Industrial Applications of Radioactivity

Technical details of representative new radioactive devices serving as resistors, electrostatic voltmeters, light sources, tube cathodes, area measurers, liquid level detectors, galvanometers, semimicrobalances, leveling systems, and micrometers

QUANTITY PRODUCTION of radioactive isotopes as a byproduct of the uranium pile has stimulated interest in older industrial applications of radioactivity and has resulted in many new applications. Radioactive materials are available abundantly now at reasonable cost, and handling techniques have been safely standardized.

Prewar uses for radium in radiographic cylinders, as neutron sources (radium-beryllium), in luminous compounds for dials, and as static eliminators now become economically attractive to a great many industries. The last-mentioned application in particular merits reconsideration today for all equipment having static problems.

Industrial Static Eliminators

Operation of an industrial static eliminator is based upon the high ionizing power of alpha particles. These have the highest specific ionization power of all radioactive radiations; a single alpha particle can produce about 40,000 ion pairs per cm along a path in air, with the exact number depending upon the velocity of the radiation.

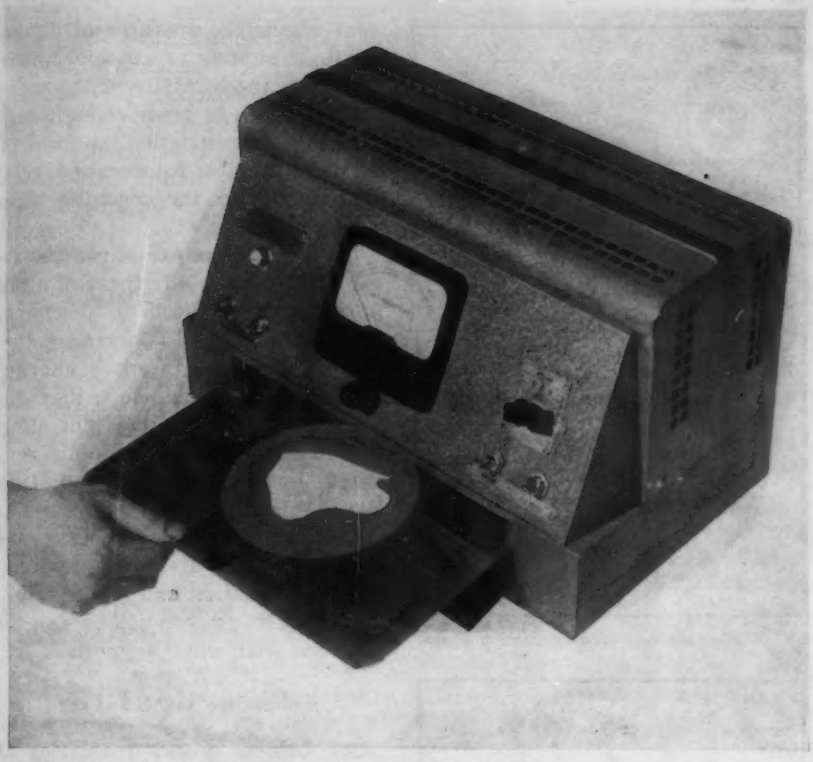
Near sources of alpha particles, air loses its insulating properties and becomes conducting, dissipating any accumulation of static electricity in nearby objects. The quantity of static electricity that can be eliminated within a certain time interval depends only on the intensity of the alpha radiation present.

The ionization effect of an alpha particle source is limited to its range, which is about 7 cm for the fastest group emitted by radium and its decay products. If the ionized air is in movement, however, as will occur in the vicinity of machines in operation or with vehicles in motion, the ionized air is transmitted appreciable distances.

Advantages of radioactive static eliminators include absence of harmful effects on commodities such as are sometimes caused by humidifiers used for the same purpose, and absence of high voltages and sparks that in themselves are fire hazards and inherently dangerous.

Since alpha particles are easily absorbed, it is necessary to apply the radioactive material in the form of a thin layer that does not introduce in itself any appreciable self-absorption. The preparation of these foils is complicated by the fact that it is necessary to retain the gaseous radon product of radium within the foil, since the escape of this gas would signify a loss of active material and create a health hazard. The total alpha activity is due to the decay products Ra A, radon, and Ra C as well as to radium.

Polonium may be used instead of radium as an alpha particle emitter. It is a pure alpha radiator, with no



Radioactive integrator being used to measure area of irregular piece of cardboard placed on circular polonium-covered plate. Meter reading, proportional to area, is obtained immediately when slide is pushed into instrument

By M. BLAU and J. R. CARLIN*

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Janesville, Wisconsin

penetrating gamma radiation, hence large areas of polonium sources can be used without introducing health hazards. However, the short half-life of polonium makes it necessary to replace this type of static eliminator after a certain time interval. Other pure alpha radiators having longer half-life are not yet available, but these elements may be ready for industrial purposes in the near future.

One millicurie of a radioactive element represents the quantity of this element that emits the same number of particles per second as one milligram of radium (3.7×10^7 particles). The ionization current produced by 1 mg of radium is about 2×10^{-4} ampere and that from 1 millicurie of polonium is 4.4×10^{-7} ampere at saturation voltage. The current from radium is greater than that from polonium because the Ra foil has additional radiation decay products.

Saturation voltage is the voltage necessary to draw all ions out of the field immediately upon formation, so that no losses occur through recombination. The field strength is about 250 volts per cm for 100 micrograms of radium or 500 microcuries of polonium coated on one square inch of radioactive foil. Therefore, the formation of 2×10^{-7} coulomb per second can be easily dissipated by these amounts of radioactivity. This accumulation of static, if not dissipated, would lead within 1 minute (assuming a capacitance of 20 $\mu\mu$f per square inch) to a voltage of about 600,000 volts, clearly a potential danger.

The more recent applications of radioactivity in industry may be divided into four groups: (1) applications utilizing the ionization power of the radiation; (2) applications utilizing penetrating properties; (3) devices in which motions or displacements are detected by radioactive substances coupled by some means to these movements; (4) applications based upon the easily recognizable radiations and their detection methods, such as tracer methods.

Only the first three groups of applications will be taken up here, since the fourth would require quite an extensive paper by itself.

Using Ionization Power

The ability of alpha or beta- emitting radioactive substances to ionize gases or air is utilized in a radioactive resistor, the terminals of which are the electrodes of an ionization chamber arranged as in Fig. 1.

One electrode is covered with a radioactive alpha-particle emitting substance, and the other is connected to an electrometer or amplifier. As the voltage between the electrodes is increased, the ionization current will increase correspondingly until saturation is reached, as shown in Fig. 2, when all of the ions are being drawn to the electrode upon formation. If voltage is still further increased, ionization by collision occurs and the current increases as in an avalanche.

The initial linear portion of Fig. 2, called the ohmic region, lends itself to the construction of resistors distinguished by complete absence of polarization and temperature deficiencies. It is true that the outside pressure, if the chamber is not hermetically sealed, or outside temperature, may somewhat influence ionization current; however, this influence is small, completely regular, simple to compute, and easily compensated for.

Radioactive resistors have long been used as leakage resistors of electrometers in radioactive labora-

NEW TOOL

Availability of radioactive products of the chain-reacting pile has fostered experimental development of new devices for measurement, detection, and control.

The representative examples cited here may be the inspiration for solution of many other perplexing industrial problems

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tories. They are equally useful in electronic circuits requiring high values of grid resistance; the higher the resistance value, the less radioactive material is needed. By varying the distance between the electrodes or varying the number of ionizing particles with diaphragms or other means, a single unit may well serve for several ranges and purposes.

Radioactive resistors remain substantially constant in value if the radioactive material used has a long half-life, such as uranium or radium. The decay characteristic of materials with short half-life permits construction of decaying radioactive resistors, which increase in resistance as they age. These make possible the longer use of relatively shorter-living radioactive material in electronic circuits. Decaying radioactive resistors are connected to counteract circuit changes produced by decay of the main radioactive material.

For instance, if polonium with a 140-day half-life is used in the main ionization chamber of a radioactive instrument, plate current decreases 0.5 percent per day. Normal means for compensation by lowering the position of the operating point on the characteristic curve of the first amplifier stage does not restore completely the original conditions. With a polonium resistor in the grid circuit, however, decay of its activity increases the grid resistance in such a manner that the plate current remains constant. The limit of the usefulness of decaying radioactive substances is then determined only by the leakage current of the insulating material employed. The same method can be used with any other natural or artificially radioactive elements.

Radioactive Electrostatic Voltmeter

The radioactive resistor can also be used for measuring high voltages. It will be especially useful where only a small current can be drawn from the source.[1] By varying the quantity of emitted radiation or the distance between the electrodes, a wide range of voltages can be covered. The ionization current, which is proportional to the applied voltage in the ohmic portion of the characteristic curve, can be measured by means of amplifiers. Measurements should be made over two ranges to insure against using a reading corresponding to saturation current.

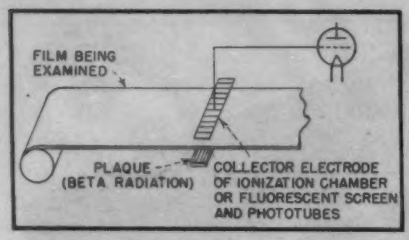
FILM BEING EXAMINED
PLAQUE (BETA RADIATION)
COLLECTOR ELECTRODE OF IONIZATION CHAMBER OR FLUORESCENT SCREEN AND PHOTOTUBES

FIG. 4—Radioactive thickness gage for moving sheets

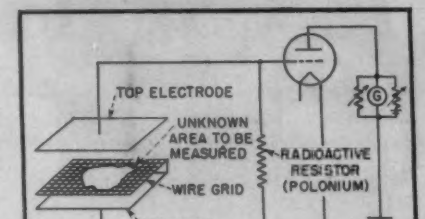

FIG. 5—Radioactive area-measuring device

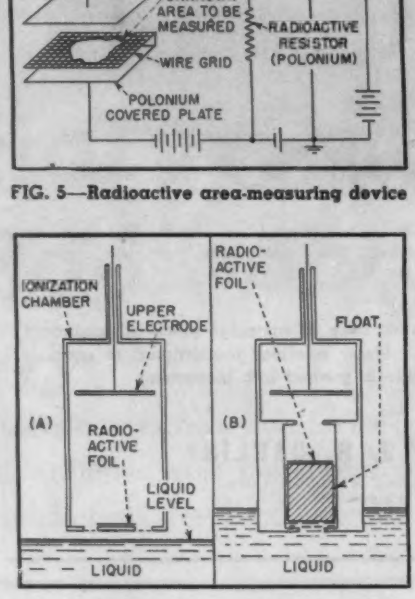

FIG. 6—Radioactive liquid level detectors

The degree of static electricity accumulated on parts of a machine can be determined by means of a metal strip coated with a radioactive alpha particle emitter. The strip is placed near a part of the machine where an excess of charge might lead to fire hazards or any other undesirable event, and is connected to the grid of an electronic tube or directly to a sensitive galvanometer. The metal strip should be well insulated from the ground.

Radiation intensity and distance between activated metal foil and machine are so chosen that under normal conditions the ionization current is zero (ohmic region) or is balanced to zero by a compensating circuit. Any increase in current warns the operator of danger by light signals or an appropriate meter. If the intensity of the radioactive source is great enough or if sufficient amplification is used, it becomes possible to operate a relay that will stop the machine automatically.

The ionizing power of radioactive radiations, especially those of alpha particles, is utilized in discharge tubes to lower the sparking potential or to dissipate space charge[2]. These applications use either the direct radiation or the light effect due to fluorescent compounds activated by the particle radiation. While relatively great quantities of radioactive materials are necessary to change the discharge appreciably, stabilization and reproducibility of existing conditions can be obtained with small amounts.

Radioactive Light Sources

As soon as great quantities of radioactive materials become available at decreased prices, innumerable applications will present themselves. Light sources of various colors, requiring no battery or power line connection, can be produced by bombardment of fluorescent compounds with radioactive radiations. The life of these sources will depend upon the half-life of the radioactive element and the stability of the luminous compound.

A radioactive light standard has already been developed[3], using radium as a constant radioactive power source. The fluorescent compound is exposed to the radiation only during short intervals (the radium foil can be easily removed), hence does not suffer any change.

The inherent constancy of radioactive light standards has one application as a radioactive pyrometer, utilizing the known principle that the brightness of certain fluorescent substances irradiated with alpha particles varies inversely with temperature. This effect is illustrated in Fig. 3 for a polonium preparation serving as alpha source and a special short-persistence type of zinc sulfide serving as the fluorescent material. Light emission ceases at a temperature of about 150 C for this material, but other compounds are available for higher temperature ranges. The method

lends itself to control of the rate of temperature change in tempering processes. The same effect is produced by x-rays or ultraviolet light, but a radioactive source gives constant output along with freedom from servicing.

Radioactive Cathodes for Tubes

In vacuum tubes, artificially radioactive substances can serve in place of heated cathodes, with such advantages as constancy of emission and uniformity of energy. The emitted beta particles carry electric charges and hence can serve in place of electron beams if radiation density is sufficiently high. If the beam of beta particles is concentrated by electric or magnetic methods, high electric charges can be accumulated, or heat and light effects can be produced.

Gamma radiation has long been used in industrial radiographic work. More recently, neutrons are being used for measuring thickness and density of heavy materials and checking uniformity, and beta particles are being used for examining light atomic substances.

Applications Using Penetrating Properties

A scanning device for testing homogeneity and thickness of films during production utilizes beta radiation from Ra B and Ra C plaques. In these, a highly concentrated radium compound is covered air-tightly by a thin metal foil in order to permit a maximum output of beta radiation. The beta radiation may also be obtained from an Ra E plaque, which uses an Ra D source in equilibrium with its decay products and covered with an extremely thin metal layer in order to absorb the alpha particles of polonium since they are not needed.

The scanning device uses a decay-compensating method. The beta radiation penetrating a standard film is compared to that going through the sample film. The emergent radiation can be measured directly by the ionization effect produced in two identical ionization chambers, or indirectly by phototubes responding to the light effect produced on fluorescent compounds, as indicated in Fig. 4. With highly explosive material where even the smallest currents must be avoided, the light effects can be compared by visual methods.

Beta radiation can also be used efficiently in comparative methods for measuring changes in composition of organic liquids in tanks or inaccessible locations. The absorption coefficient of beta radiation is relatively high compared to gamma radiation, so that even slight changes in density are easily discernible.

The range of alpha particles in solid matter is only of the order of 100 microns, precluding examination of thick materials, but these alpha particles are extremely useful in detecting the presence or absence of even the smallest quantities of solid matter in space. The radioactive integrator[4] for measuring irregular areas, shown in Fig. 5, is an application of this principle. A plate uniformly covered with polonium is positioned far enough below a wire mesh grid so that only the most perpendicular alpha radiation can ionize the space between the grid and the top electrode. If a plane surface of unknown area is placed on the grid, the ionization current will be reduced by an amount proportional to this area. The grid mesh is connected to the lower plate. Use of a radioactive grid resistor of polonium keeps the plate current of the tube constant for equal surfaces in spite of the decay of polonium.

The radioactive arrangement of Fig. 5 can also be used to measure porosity and open areas of mesh surfaces, integrate the values of curves or charts that have been cut out along their peripheries, determine the most efficient layouts of patterns to be cut or stamped from metals or fabrics, and measure areas of such things as precious metals, foils, furs, and leathers. If the radioactive plate is coated with a beta emitter the apparatus can be used for thickness or density measurements of plastic or organic materials, and for volume determinations. For metallic materials the radioactive energizing material should be a gamma-ray emitter.

Measuring Liquid Levels

The absorption coefficient of alpha particles is used in the liquid level indicating arrangement of Fig. 6A[5]. As long as the source of alpha particles is in gaseous atmosphere, an ionization current is maintained. When the liquid level rises or the ionization chamber is lowered, so that a slight layer of liquid (less than 1 mm thick) covers the radioactive foil, the ionization current ceases and the plate current of the associated amplifier tube is appreciably reduced. Surface tension effects can be minimized by appropriately shaping the foil and covering it with a thin layer of liquid-repelling material.

Another possible level-detecting arrangement is shown in Fig. 6B, where the alpha particle source is on a float. As the float rises, the source comes closer to the collector

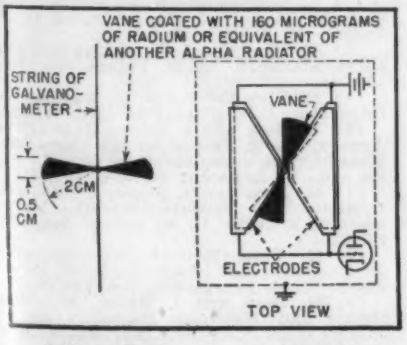

FIG. 7—Radioactive galvanometer

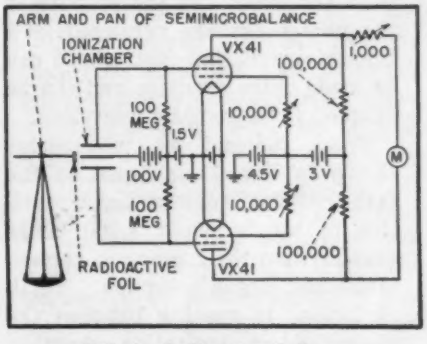

FIG. 8—Radioactive balance

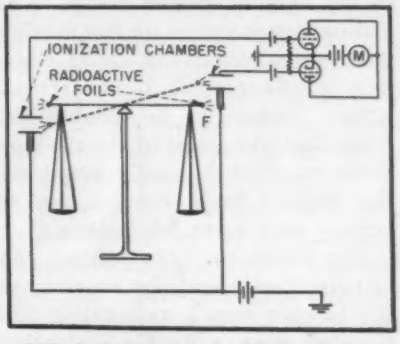

FIG. 9—Radioactive limiting balance

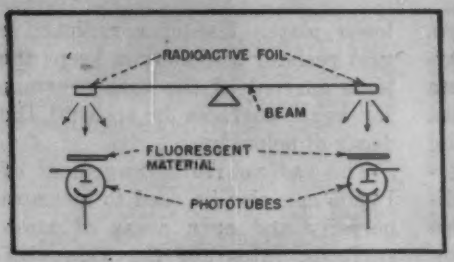

FIG. 10—Radioactive levelling method

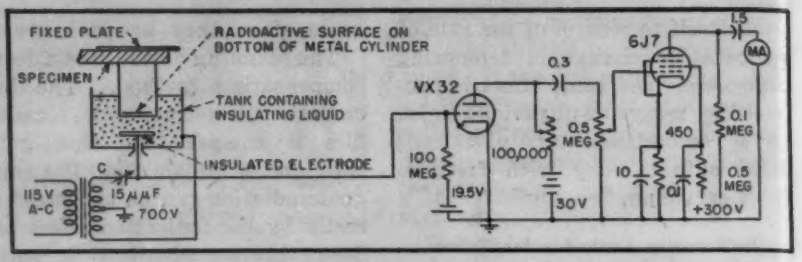

FIG. 11—Radioactive micrometer arrangement and circuit

electrodes and the ionization current increases.

Radioactive level-indicating devices can be made much more elaborate when high precision is required. Furthermore, the ionization current can be used to actuate a relay and motor control circuit when a fully automatic remote-reading apparatus is needed.

The same principle of interrupting the ionization current of a beam of alpha particles by the smallest quantities of liquid can also be applied to surface tension meters.

Detecting Displacement

When radioactive material is coupled directly or indirectly to the moving part of a system, variations in position cause variations in ionization current or light effect that are readily amplified to give practically any degree of sensitivity and precision.[6, 7]

A typical application here is the radioactive galvanometer, in which a vane appropriately plated with radioactive material is attached to the moving system in place of a mirror, as indicated in Fig. 7. With a simple one-tube amplifier, a rotation of one minute here would lead to a change of between 10 and 20 microamperes in plate current for the vane dimensions shown. With appropriate refinements, the sensitivity can be even further improved.

The above technique is applicable to any type of torsion meter. The radioactive material on the moving part can alternatively cause emission of fluorescent light from a screen monitored by phototubes. Since ionization and phototube currents can both be easily amplified, the method lends itself nicely to remote reading or telemetering.

The movement of a balance can be magnified greatly by coupling to the balance arm a radioactive foil situated near a double ionization chamber, as in Fig. 8. With the arm length of an ordinary semimicrobalance, the radioactive adaptation was capable of recording variations of 1 microgram. The accuracy of a microbalance was thus combined with the ruggedness of a semi-microbalance. The radioactive balance has the further advantage of indicating directivity above or below an equilibrium position.

The radioactive balance arrangement shown in Fig. 9 can be used for production weighing of small quantities of material within a predetermined accuracy.[8] The vertical positions of the ionization chambers can be adjusted so that maximum meter reading occurs when a predetermined weight of material is in one balance pan. The sharpness of the peak of the maximum reading can be adjusted by means of diaphragms at the openings of the ionization chambers, to give the degree of accuracy desired. With high enough radioactive intensities or increased amplification in the output circuit it would be possible to energize a relay controlling a valve that would permit only a certain amount of material to flow onto the balance pan.

A radioactive arrangement suitable for leveling or for determining the degree of inclination is shown in Fig. 10. Any deviation from a horizontal position of the beam increases the current in one phototube and simultaneously decreases it in the other. If the outputs of the phototubes are arranged in a bridge circuit, the instrument can be made quite sensitive and can be adapted for automatic releveling.

The radioactive micrometer shown in Fig. 11 is based on the fact that the range of alpha particles in air is about 1,000 times greater than their range in certain insulating organic liquids. Small variations in spacing between the plates of an ionization chamber situated in such a liquid give a considerable percentage change in ionization current. The spacing is determined by the thickness of the specimen being measured. It is possible to measure the heat extension of materials within an error of $\pm 1 \times 10^{-6}$ inch. While the maximum change in length or thickness covered by this instrument depends upon the range of the radiation and the stopping power of the liquid, it is possible to measure greater changes by appropriate displacement of one of the electrodes.

To avoid polarization of the liquid, a-c voltages are applied to the ionization chamber. Capacitor *C* is used to nullify the alternating current that would flow through the capacitance of the ionization chamber to the grid of the first tube. The operating point of the first tube is chosen to minimize the ionization current that would flow during the inverse portions of the applied voltage.

The devices discussed in this paper are merely representative examples of the forerunners of a wide range of industrial applications. The number of these will increase immeasurably with the progress of the science of radioactivity and the increasing availability of its raw materials.

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(2) L. Goldstein and F. Perrin, Cold Cathode Gaseous Discharge Tubes, U. S. Patent No. 511,398.
(3) M. Blau and I. Feuer, Radioactive Light Standard, U. S. Patent Ser. No. 686,704.
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(6) M. Blau and I. Feuer, Method for Detection and Measurement—The Movement of a Body, U. S. Patent Ser. No. 731,380.
(7) M. Blau, Method and Apparatus for Indicating and Measuring Small Movements, U. S. Patent Ser. No. 744,234.
(8) M. Blau and I. Feuer, Weighing Device and Weighing Method (limiting balance), U. S. Patent Application Ser. No. 748,636.

R-F Bridge for Broadcast Stations

Versatile unit incorporates variable-frequency signal generator, calibrating oscillator, bridge circuit, detector and batteries in a single lightweight unit. Principles of operation are outlined and constructional data are given

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WSIX
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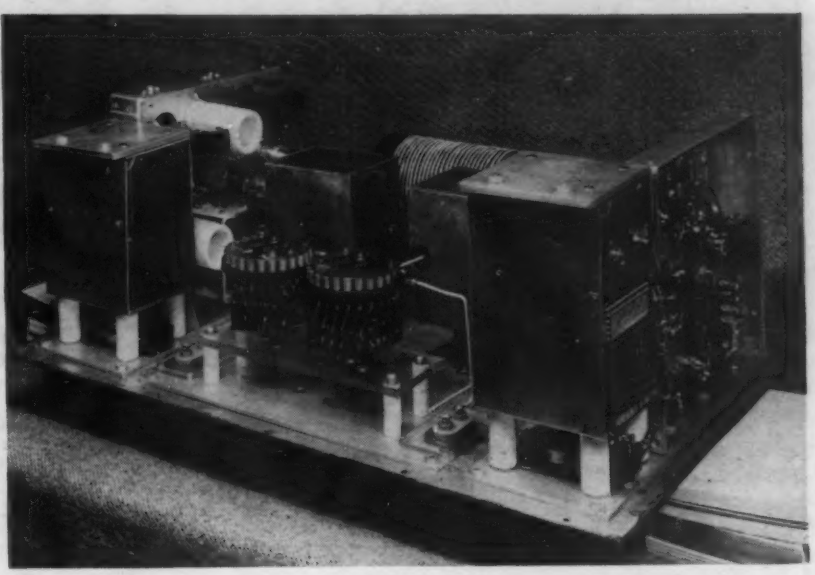
ONE OF THE most useful pieces of equipment in a broadcast station is a reliable, easily portable radio-frequency bridge. This is particularly true for the station with a multi-element antenna array where checks on self and mutual antenna impedances, driving-point impedances, and common-point impedance are frequently desirable.

The bridge to be described contains an oscillator crystal-controlled at the station frequency, in this case 980 kc, and an electron-coupled oscillator which can be calibrated at the station frequency by means of the crystal oscillator and then varied about 60 kc each side of this frequency. The oscillator is modulated at 1,000 cps. Following the oscillator is the bridge proper and then a sensitive receiver with an audio amplifier sharply peaked at 1,000 cps. The latter arrangement is particularly to be desired when making antenna measurements during times of heavy static.

The power supply consists of batteries which are contained within the apparatus. The compactness of this arrangement will be appreciated by anyone who has had to make the usual setup of a signal generator, bridge and receiver upon a small antenna base on a cold night.



Interior view of impedance bridge with cover removed and unit tipped forward to rest on front panel. Signal generator is at left; receiver is at right

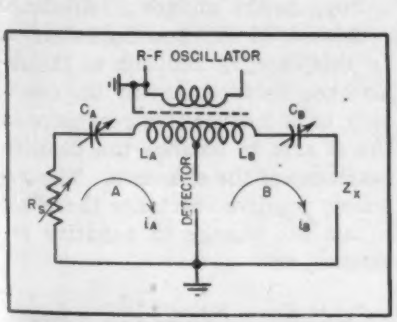


FIG. 1—Basic circuit used in r-f bridge

Theory of Operation

The basic bridge circuit, shown in simplified form in Fig. 1, is similar to the a-f hybrid coil type 4-A used for some years by the Bell System.

Assume that L_A equals L_B and that equal voltages are induced in both arms. Then i_A will equal i_B in magnitude and phase provided the self impedance of mesh *A* equals the self impedance of mesh *B*. For this condition the bridge is balanced and no voltage appears across the detector terminals.

In practice, before making a measurement an initial balance is made with the unknown terminals shorted and the self-contained standard resistance *R*, set at zero. This balance is made with C_A and

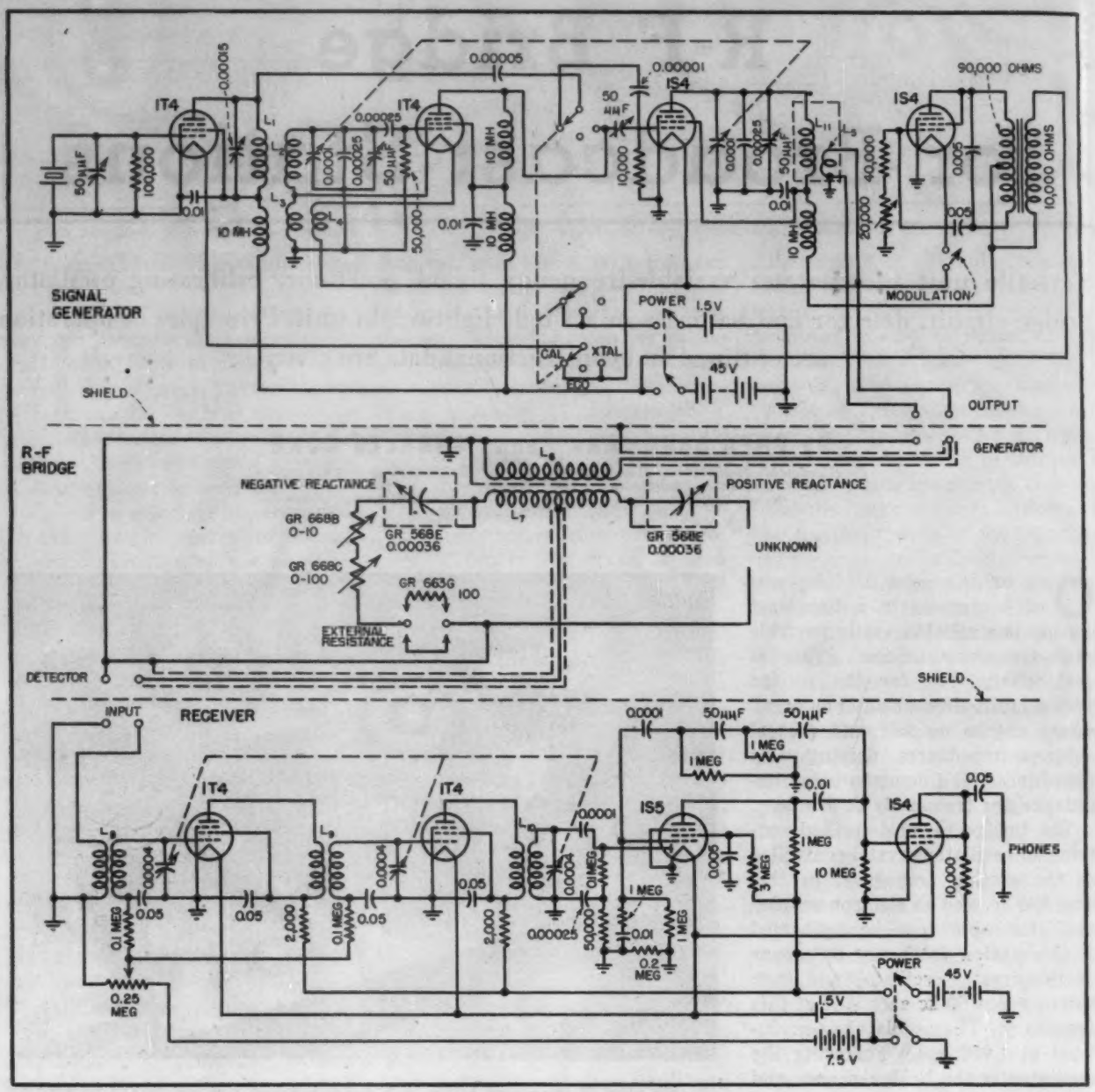


FIG. 2—Complete schematic diagram of bridge unit

C_B set as close to maximum capacitance as possible. If great care is used in balancing capacitances to ground in construction, the values of C_A and C_B in the initial balance will be practically equal. Assume now that the initial balance has been made and the two capacitance values are C_{A1} and C_{B1}. Suppose an unknown impedance consisting of R_s and C_s in series is connected to the unknown terminals. To again balance the bridge it will be necessary to add a resistance (R_s) in the A arm equal to R_s. Also, since capacitive reactance has been added in the B arm, it will be necessary to add an equal capacitive reactance in the A arm. This is done by changing C_A from C_{A1} to a lower value C_{A2}. The unknown capacitive reactance is then

$$X_{C_s} = X_{A_2} - X_{A_1} \tag{1}$$

$$\frac{1}{\omega C_s} = \frac{1}{\omega C_{A_2}} - \frac{1}{\omega C_{A_1}} \tag{2}$$

$$C_s = \frac{C_{A_1} C_{A_2}}{C_{A_1} - C_{A_2}} = \frac{D_1 D_2}{D_1 - D_2} K_A \tag{3}$$

where D_1 and D_2 are the dial divisions corresponding to C_{A1} and C_{A2} and K_A = calibrating constant of C_A where $C_A = D_A K_A$. If the unknown capacitive reactance is required this is:

$$X_{C_s} = \frac{1}{\omega C_s} = \frac{D_1 - D_2}{\omega K_A D_1 D_2} \tag{4}$$

Suppose the unknown impedance consisted of R_s and L_s in series. In this case, in addition to the resistance balance it will be necessary to add capacitive reactance in the B arm to balance the positive reactance of the unknown. The unknown positive reactance therefore equals the change in negative reactance, or

$$X_{L_s} = X_{B_2} - X_{B_1} = \frac{1}{\omega C_{B_2}} - \frac{1}{\omega C_{B_1}}$$

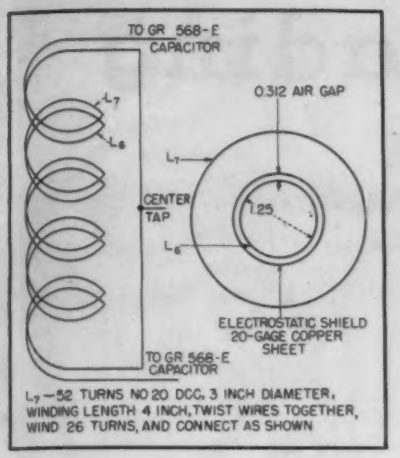

TO GR 568-E CAPACITOR
0.312 AIR GAP
L_7
L_6
CENTER TAP
1.25
ELECTROSTATIC SHIELD 20-GAGE COPPER SHEET
TO GR 568-E CAPACITOR
L_7—52 TURNS NO 20 DCC, 3 INCH DIAMETER, WINDING LENGTH 4 INCH, TWIST WIRES TOGETHER, WIND 26 TURNS, AND CONNECT AS SHOWN

FIG. 3—Construction of bridge-circuit inductor is shown at left; assembly of inductors and electrostatic shield is shown at right

$$= \frac{C_{B_1} - C_{B_2}}{\omega\, C_{B_1}\, C_{B_2}} = \frac{D_1 - D_2}{\omega\, K_B\, D_1\, D_2} \qquad (5)$$

and $$L_x = \frac{D_1 - D_2}{\omega^2\, K_B\, D_1\, D_2} \qquad (6)$$

where K_B is the calibrating constant of C_B.

In the bridge built by the authors, K_A and K_B were equal within less than 1 percent error and had a value of 1.87 $\mu\mu$f per division. The dials used had 200 divisions and the capacitors were of the straight-line capacitance type. The calibrating constants were determined by first making an initial balance and then adding specific values of known capacitances in shunt with C_A and C_B and noting the change in C_A and C_B to again balance the bridge. A curve was plotted which turned out to be an exceedingly straight line, and its slope was used in determining the values of K.

The r-f bridge, signal generator, and receiver are constructed in a single aluminum cabinet with dimensions of 22 inches by 14 inches by 8 inches. This cabinet is divided into three sections by aluminum shields and the signal generator and receiver are also individually shielded. It is necessary that no coupling exist between signal generator and bridge and between bridge and receiver except through the external connections. Stray coupling will result in a false resistance balance when measuring 100 ohms or greater.

The circuit is shown in Fig. 2.

Shielding

The construction is such as to minimize the capacitances to ground of all components and to keep these capacitances equal in each of the arms. For the purpose of eliminating changes in stray capacitances as the rotors are turned, the reactance balance capacitors are fitted with shields connected to their rotors. The induced voltages across the two parts of L_7 are kept equal and the electrostatic shielding between L_6 and L_7 is made adequate by the construction shown in Fig. 3. Since the maximum value of resistance that can be measured with the internal components is 110 ohms, binding posts are provided for connection of external standards to facilitate the measurement of large resistances or to obtain steps of less than one ohm. All grounds are made to the cabinet at a single point to prevent introduction of undesired voltages from the signal generator through common ground-return impedances.

Plug-in type coils are used throughout the signal generator built into this apparatus and new bands of frequencies can be added if desired. An r-f isolation amplifier is used to minimize oscillator frequency change with varying load conditions and its tuning control is ganged with the electron-coupled oscillator control for single-dial tuning. The electron-coupled oscillator is capable of maintaining its frequency calibration with good accuracy over considerable periods of time and can be adjusted to zero beat with the crystal oscillator at 980 kc by operating the oscillator control switch to the CAL position and adjusting the 50 $\mu\mu$f trimmer in the grid circuit.

The modulator uses a Hartley oscillator circuit and is tuned to 1,000 cps. Small variations in frequency are corrected by adjustment of the grid resistor. The r-f output voltage, which can be modulated approximately 50 percent, is one volt across 50 ohms impedance. The B-battery drain is 10 ma and the A drain is 250 ma under normal operating conditions.

The receiver, employing a trf circuit, can be tuned over the broadcast band. A feedback network between plate and grid of the first audio stage sharply peaks the audio response at 1,000 cps, greatly facilitating measurements on antennas in the presence of atmospheric static and interference from other stations. The B-battery drain is approximately 6 ma and the A drain is 250 ma.

Accuracy

While it is not claimed that this bridge is more accurate than others, it is believed that the obvious advantages offered by its compact arrangement will make its use worthwhile. The bridge, when checked against one of known high accuracy, proved to be within 2 percent for reactance and resistance values in the ranges commonly used in broadcast work.

The authors wish to acknowledge the valuable suggestions received from several members of the technical staff of WSM during the construction of this device.

Table I—Coil Winding Data

Circuit Symbol	Number of Turns	Size dcc Wire	Winding Diam. (inches)	Notes
L_1	90	32	1.5	Closewound. For 980-kc crystal
L_2	44	32	1.5	Closewound. For eco range of 920–1,050 kc
L_3	12	32	1.5	Interwound with L_4 at end of L_2
L_4	12	32	1.5	Interwound with L_3 at end of L_2
L_5	12	22	1.5	Closewound at end of L_{11}
L_6	45	20	1.25	Closewound. See Fig. 3
L_7	52	22	3	Length 4 inches. See Fig. 3
L_8	Commercial antenna coil to cover broadcast band with tuning capacitance used			
L_9, L_{10}	Commercial r-f coils to cover broadcast band with tuning capacitance used			
L_{11}	54	26	1.5	Closewound. For tuning range of 920–1,050 kc

Instant-Reading

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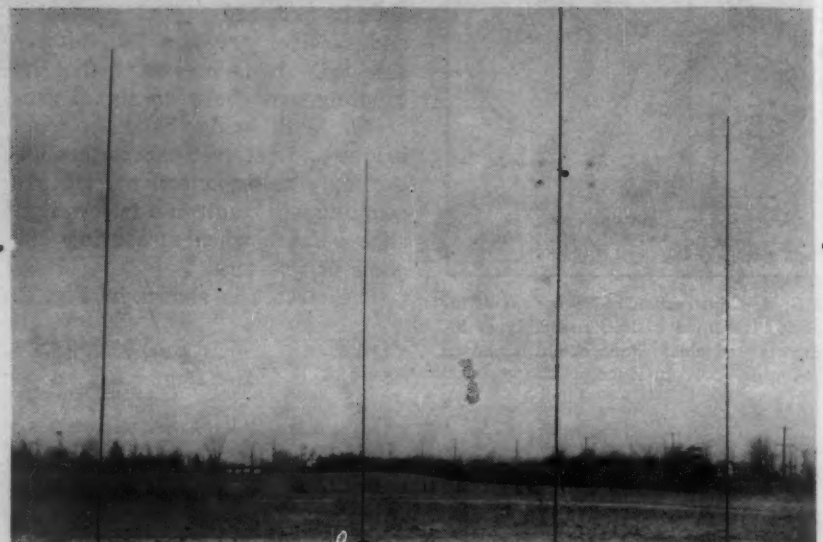

FIG. 1—Antenna system, balanced modulators, and a combining impedance make up an electronic goniometer. Modulators are housed in junction boxes at base of masts; combining impedance is in junction box at center. This prototype antenna has no top loading skirts, but these are included in later models

THE art of radio direction finding was advanced materially by wartime research, although the recent sensational disclosures of radar techniques have largely obscured this fact. This paper describes an electronic direction-finding method and several advanced instrumental features which are incorporated in a new Signal Corps direction finder, Radio Set AN/CRD-2.

This direction finder produces automatic visual bearing indications on the vertically polarized components of either sky-wave or ground-wave signals in the frequency range of 0.54 to 30 mc. The set embodies several novel features intended to enlarge the operational usefulness of direction finding, particularly in applications such as the monitoring and administrative control of aircraft flights, aircraft navigation and homing, rescue operations, and the location of illicit transmitters. Unusually high operating sensitivity and bearing accuracy are achieved through the use of an all-electronic principle of operation. All moving mechanical parts have been eliminated, thus providing structural simplicity as well as ease of operation and maintenance.

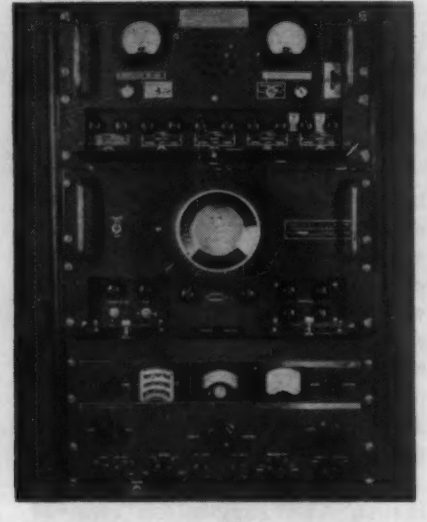

FIG. 2—Operating rack contains modulating-voltage generator (above), bearing indicator (center), and standard communications receiver (below)

System Elements

Structurally, the direction finder comprises the fixed-position spaced-collector antenna system shown in Fig. 1 and the operating rack shown in Fig. 2. Weatherproof junction boxes at the bases of the antenna masts contain electronic circuits which, in combination with the four spaced collectors, constitute an aperiodic electronic goniometer. A wire netting, 75 feet square and composed of 18-inch mesh, is installed under the antenna system and serves as a counterpoise. When this counterpoise is properly terminated at the edges, the accuracy of the direction finder is substantially independent of soil constants.

For operation in the frequency range of 0.54 to 6.0 mc, a mast height of 30 feet and a diagonal spacing of 34 feet are used. For operation between 6.0 and 30.0 mc, the antenna system is erected with a 24-foot mast height and a 17-foot diagonal spacing. A top loading skirt composed of six radial spokes, each three feet long, is installed at the top of each antenna mast and is used at all frequencies. No particular improvement in performance results from use of the loading skirts at frequencies above 10 mc, but sensitivity and antenna balance are greatly enhanced at lower frequencies.

The operating rack contains a standard single-channel communications receiver, c-r tube bearing indicator, and a control panel. The rack may be placed at any convenient distance up to about 1,000 feet away from the antenna system. In airport installations, for example, it is possible to install the rack in the control tower for operating convenience and place the antenna system on an unobstructed site away from buildings and power lines.

Direction Finder

Heart of this new direction finder is an electronic goniometer circuit that modulates incoming signals with angle-of-arrival intelligence. Bearings are indicated by propeller-shaped pattern on c-r tube screen. Switch-operated circuits produce sense indication or split bearing pattern to indicate accurately directions of weak signals

From a functional point of view, the equipment consists of a substantially aperiodic electronic goniometer which receives all of the signals within a wide frequency spectrum and imposes upon each received signal a low-frequency modulation envelope having a phase that depends on direction, a receiver which selects and rectifies the desired signal, and a c-r tube phasemeter which translates the envelope phase of the selected signal into an indication of direction.

Operation of the direction finder is as simple as tuning a receiver; the desired signal is simply tuned in and a propeller-shaped indicating pattern appears automatically on the indicator screen. A photograph of a typical bearing indication is shown in Fig. 3. The tips of this pattern indicate the direct and reciprocal bearings against an azimuth scale around the screen. Identification of the direct bearing is accomplished by pressing a sense switch to produce a folded pattern as shown in Fig. 4. This folded pattern can be regarded as an arrowhead pointing to the direct bearing.

Electronic Goniometer

The operation of the electronic goniometer can best be explained with reference to the functional block diagram shown in Fig. 5.

The antenna system consists of four omnidirectional collectors, N, E, S, and W, uniformly disposed on the circumference of a circle. If the field of the received wave at the center of the antenna system is taken as a phase reference and denoted by $E = E_M \sin \omega_c t$, then the signal voltages induced in the individual collector elements may be represented by the following equations:

$$e_N = E_M h_e \sin\left(\omega_c t + \frac{2\pi d}{\lambda}\cos\alpha\right) \quad (1)$$

$$e_E = E_M h_e \sin\left(\omega_c t + \frac{2\pi d}{\lambda}\sin\alpha\right) \quad (2)$$

$$e_S = E_M h_e \sin\left(\omega_c t - \frac{2\pi d}{\lambda}\cos\alpha\right) \quad (3)$$

$$e_W = E_M h_e \sin\left(\omega_c t - \frac{2\pi d}{\lambda}\sin\alpha\right) \quad (4)$$

where E is the received field strength in volts per meter, h_e is the effective length of each collector element, ω_c is the angular frequency of the received signal, d is the distance from the center of the antenna system to each collector element, λ is the wavelength of the received signal, and α is the direction of wave arrival measured clockwise from north.

In the usual four-element spaced-collector systems,[1] the north and south collector elements are combined in opposition to produce a figure-eight horizontal directivity pattern and, in a like manner, the east and west elements are combined to produce a second figure-eight pattern displaced 90 degrees from the first. The individual outputs of the two pairs of collectors are then usually applied to the field coils of a rotatable goniometer or to the two inputs of a twin-channel receiver.

This system differs from conventional systems in that the collector elements are not combined directly in pairs to produce the customary crossed figure-eight polar patterns. Instead, the signal output of each collector element is modulated independently in an individual balanced modulator. The signals from alternate collector elements are modulated in quadrature. In this manner, the following four equal-amplitude carrier-suppressed modulated signals are produced:

$$e'_N = E_M K \sin\left(\omega_c t + \frac{2\pi d}{\lambda}\cos\alpha\right)\cos\omega_M t \quad (5)$$

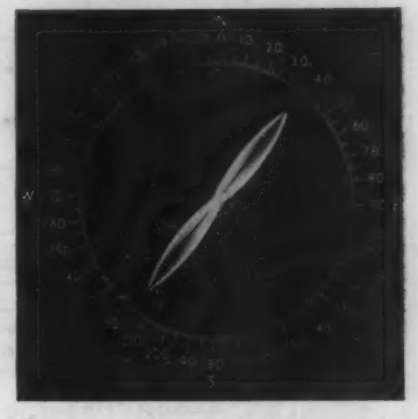

FIG. 3—In this typical indicator pattern, propeller tips serve as pointers to indicate bearing. This pattern has 180-degree ambiguity, necessitating auxiliary means for determining sense

FIG. 4—Throwing a sense switch folds back propeller tips form arrowhead pointing in true direction of signal. This sense pattern resolves the ambiguity of Fig. 3

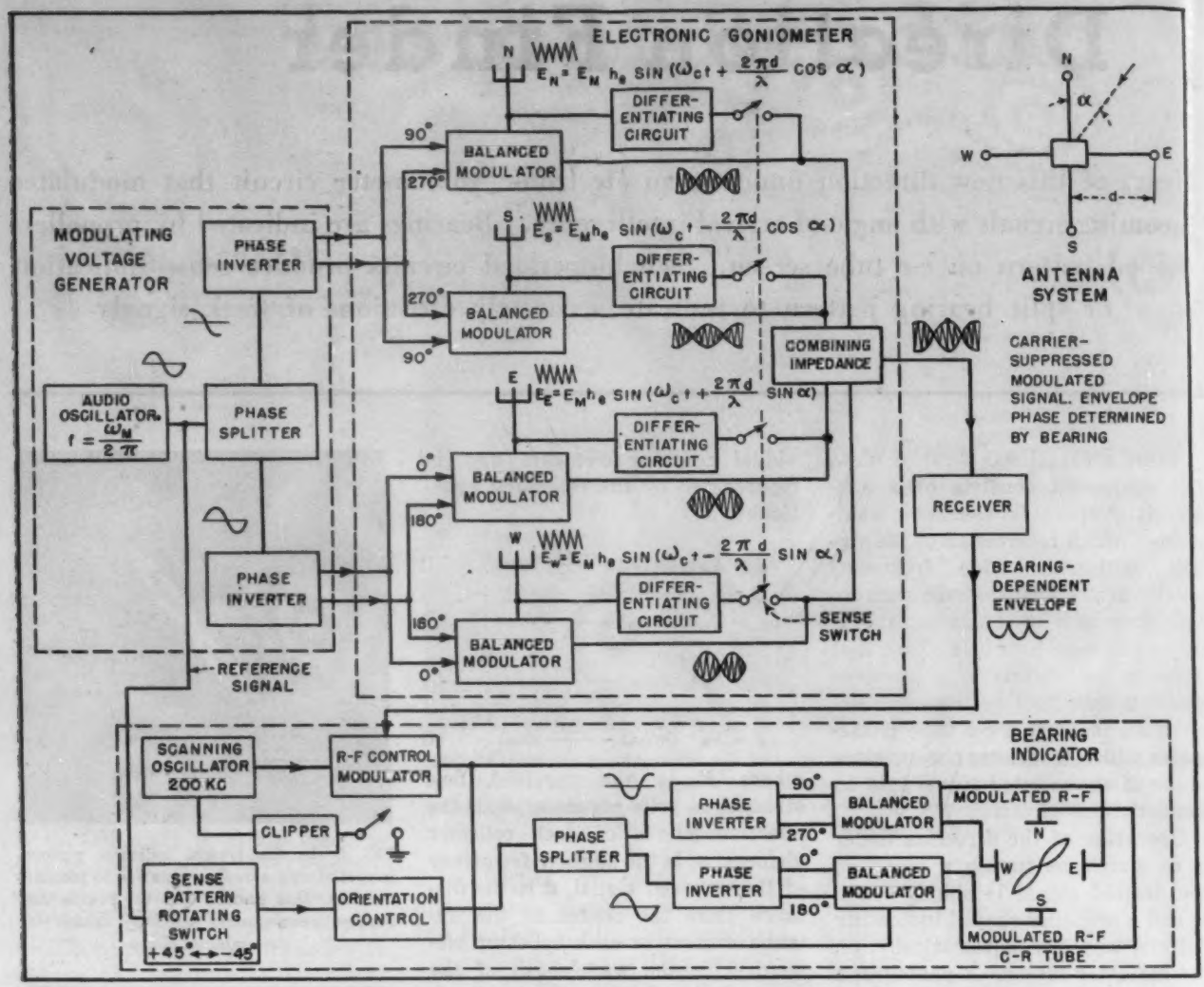

FIG. 5—Block diagram of the electronic direction finder

$$e'_N = E_M K \sin\left(\omega_c t + \frac{2\pi d}{\lambda}\sin\alpha\right)\sin\omega_M t \quad (6)$$

$$e'_S = -E_M K \sin\left(\omega_c t - \frac{2\pi d}{\lambda}\cos\alpha\right)\cos\omega_M t \quad (7)$$

$$e'_W = -E_M K \sin\left(\omega_c t - \frac{2\pi d}{\lambda}\sin\alpha\right)\sin\omega_M t \quad (8)$$

where K is a constant taking into account the effective length h_e and the conversion characteristics of the balanced modulators and ω_M is the angular frequency of the modulation.

It will be noted from Eq. 5 to 8 that each carrier-suppressed signal has a fixed envelope phase but the high-frequency phase is a continuous function of α, the horizontal direction of wave arrival.

Now, these four equal-amplitude modulated signals are combined additively in a common impedance to produce a resultant signal, e_R, expressed exactly by

$$e_R = 2E_M K\left[\sin\left(\frac{2\pi d}{\lambda}\cos\alpha\right)\cos\omega_M t + \sin\left(\frac{2\pi d}{\lambda}\sin\alpha\right)\sin\omega_M t\right]\cos\omega_c t \quad (9)$$

In practice, the spacing factor, d/λ, is usually small. The following small-angle approximations may, therefore, be employed to reduce Eq. 9 to a form in which the physical significance is more readily apparent:

$$\sin\left(\frac{2\pi d}{\lambda}\cos\alpha\right) \approx \frac{2\pi d}{\lambda}\cos\alpha \quad (10)$$

$$\sin\left(\frac{2\pi d}{\lambda}\sin\alpha\right) \approx \frac{2\pi d}{\lambda}\sin\alpha \quad (11)$$

Accordingly, for an antenna system with small electrical spacing between collectors, the resultant signal is adequately expressed by

$$e_R \approx \frac{4\pi d}{\lambda}\cos(\alpha - \omega_M t)\cos\omega_c t \quad (12)$$

The antenna system with its associated balanced modulators is called an electronic goniometer because each signal in the output of the system has angle-of-arrival intelligence imposed upon it. This intelligence is implicit in the phase of the low-frequency envelope of the carrier-suppressed modulated signal expressed by Eq. 12.

Figure 6 is a simplified schematic diagram of the electronic goniometer and sensing circuits. The tubes and associated circuits within each dotted enclosure are installed in a weatherproof junction box at the base of an antenna mast. The signal derived from an antenna, for example the north antenna, is applied in phase to the grids of tubes T_1 and T_2. The plates of these tubes are connected in push-pull through a pair of coaxial cables to the r-f transformer designated as combining impedance. Modulating signals having a frequency of 147 cps are applied push-pull to the grids of the

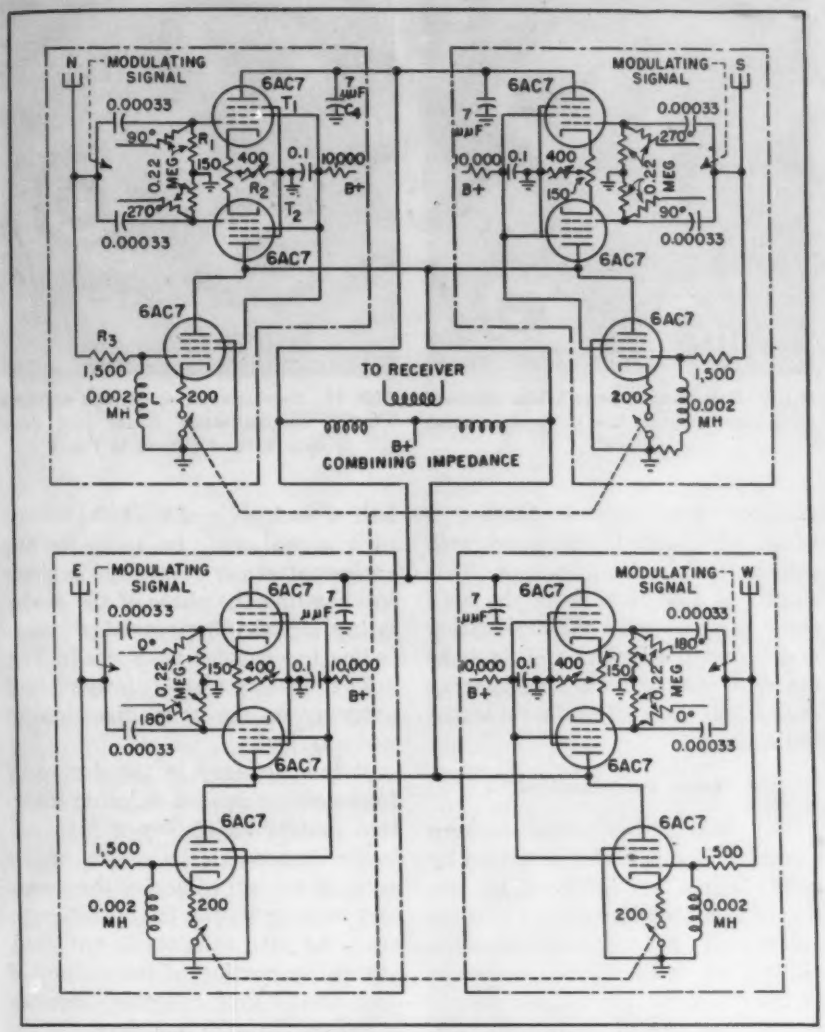

FIG. 6—Schematic diagram of the electronic goniometer

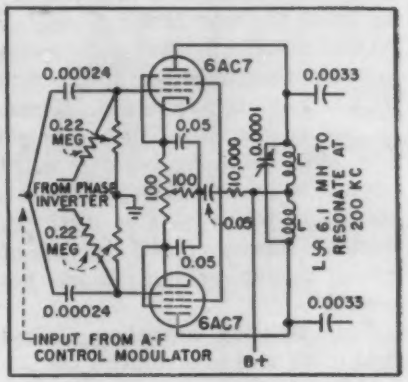

FIG. 7—Balanced modulator used in indicator

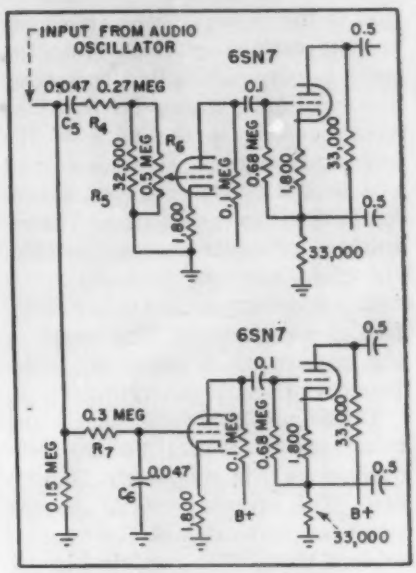

FIG. 8—Phase splitter and inverter

tubes. Tubes T_1 and T_2 thus constitute a balanced modulator. A potentiometer R_1 on the control panel in the operating rack serves to balance the initial gains of the two tubes of the modulator, and a variable resistor R_2 adjusts the initial operating level of the entire modulator. These controls are readjusted only as the tubes age and their settings are not particularly critical. Tube T_3 and its associated circuits are part of the sensing arrangement and will be described later. Capacitor C_4 compensates for the unbalancing effect of the output capacitance of the sense tube T_3.

The modulators are designed to be substantially aperiodic. In addition to serving as part of the electronic goniometer, the tubes used in the modulators isolate the antennas, a fact of considerable importance in regard to polarization errors. These tubes also transform the antenna impedance for effective coupling to low-impedance transmission lines.

The receiver employed is entirely conventional. The detector output from the receiver is a rectified envelope having a direction-dependent phase. This envelope is applied to the bearing indicator.

As previously stated, the bearing indicator in this direction finder is essentially a c-r tube phasemeter used to translate the envelope phase of a selected signal into an indication of direction.

The sinusoidal output of a 200-kc scanning oscillator is applied in phase to a pair of balanced modulators. Modulating signals having an angular frequency of ω_M are applied to the balanced modulators in phase quadrature. The output of one balanced modulator is applied to the vertical deflection plates of the c-r tube and the output of the other is applied to the horizontal plates. Now, because of the quadrature modulation, the upper sideband from one modulator is in phase quadrature with the corresponding sideband from the other modulator. Since these upper sidebands are applied to space-quadrature deflection plates, they produce a circularly polarized deflecting field within the c-r tube. Similarly, the lower sidebands from the two modulators produce a second and oppositely directed circularly polarized field.

According to a principle well known in optics,[3] two oppositely directed circularly polarized fields of the same period combine to produce a linearly polarized field. If the relative phase of the fields is changed, the plane of rotation of the resultant linearly polarized field is rotated through an angle equal to half the change of phase.

In the c-r tube, the two circularly

polarized fields differ in frequency by twice the modulating frequency so that the effective phase difference between them changes at the rate of $2\omega_M$ radians per second. Hence, in accordance with the principle just stated, the c-r beam is acted upon by a linearly polarized deflecting field which rotates with an angular velocity of half the rate of phase change or ω_M radians per second.

This rotating linearly polarized field gives rise to a rotating diametral-line trace on the c-r tube. As the line rotates, its instantaneous length is varied in an inverse relation to the instantaneous amplitude of the rectified envelope from the receiver output. The line, therefore, has full length at angular positions corresponding to the nulls of the bearing-dependent envelope and zero length at positions corresponding to the envelope maxima. The resulting propeller-shaped pattern, therefore, assumes an angular orientation corresponding to the direction of wave arrival. The length of the pattern is substantially independent of signal strength.

Under no-signal conditions, a circular area on the screen of the cathode-ray tube is completely illuminated. This circular area is scanned twice per revolution of the diametral-line trace, thus resulting in the superposition of two filled-in circular patterns on the screen. The significance of this fact will become apparent when the bearing-splitting feature is described.

Indicator Operation

The indicator functions shown in the block diagram of Fig. 5 are performed with relatively simple elements. The balanced modulator circuits, one of which is illustrated in Fig. 7, are identical with the antenna modulators shown in Fig. 6, except for the use of a tuned plate load. The phase-splitting and phase-inverting circuits used are illustrated in Fig. 8. A 90-degree relation between the modulating signals, regardless of oscillator frequency variations, is maintained by making C_5 and C_6 equal in capacitance and by making the resistance of R_7 equal to R_4 plus the parallel combination of R_5 and R_6. The orientation control is a continuously variable phase-shifter having a range of about 120 degrees with substantially constant output. This control is used to zero-set the indicator to agree with the orientation of the antenna system and, in some cases, to change from true bearing indications to magnetic-reference indications.

FIG. 9—This bearing pattern was obtained on a signal almost lost in receiver noise level

FIG. 10—Bearing-splitting permits accurate reading on the weak signal that gave poorly defined pattern in Fig. 9

Sense Determination

The bearing-indicating pattern shown in Fig. 3 is characterized by a 180-degree ambiguity. The two tips of this propeller-shaped pattern correspond to the two envelope minima per modulation-signal cycle of the electronic goniometer output represented by

$$e_R = \frac{4\pi d}{\lambda} E_M K \cos(\alpha - \omega_M t) \cos \omega_c t \quad (12)$$

To resolve this ambiguity, an omnidirectional sensing signal of the

$$e_S = \frac{4\pi d}{\lambda} E_M K_S \cos\omega_c t \quad (13)$$

form where K_S is a constant, is combined with the normal output e_R. If e_S is made equal to e_R, the envelope of the combined resultant signal will have a single minimum per modulation-signal cycle and ambiguity will no longer exist.

In practice e_S is made somewhat less than e_R and the resultant signal has two envelope minima per modulation-signal cycle, unequally spaced in time. The sense of the envelope dissymmetry indicates direction uniquely. Simultaneously with the addition of the sensing signal the rotating diametral-line trace on the screen of the cathode-ray tube is converted into a rotating radial-line trace by blanking the beam during half of each cycle of the 200-kc scanning signal and, in addition, the entire pattern is rotated 90 degrees by changing the phase of the modulating signal. The resulting sense-indicating pattern is shown in Fig. 4. The sense pattern is always folded away from the true direction of wave arrival.

It is customary in the design of four-element spaced-collector direction finders[1] to employ a fifth collector element at the center of the antenna system to derive the necessary sensing signal. In this set, however, the fifth collector is not used. Instead, a portion of the output of each of the four collector elements is passed through a differentiating circuit as indicated in Fig. 5 and Fig. 6. The four differentiated signals thus obtained are then combined additively to produce a sensing signal of the form specified by Eq. 13. The sensing signal obtained in this manner maintains a substantially uniform phase and amplitude with respect to the direction-dependent modulated signal e_R over a very broad frequency range. Moreover, since the sense signal and the direction-dependent signal pass through the same transmission lines and coupling impedances, no practical sensing difficulties are caused by impedance mismatches.

Sensing Circuit

The details of the sensing circuit may be seen from Fig. 6. Resistor R_2 and inductance L comprise a differentiating circuit and tube T_3 performs a coupling function. All switches shown are ganged and operated by a sense-switch bar on the

FIG. 11—Symmetrically split bearing pattern is obtained under ideal propagation conditions

FIG. 12—Diversity effects in received wavefront produce this unsymmetrically split pattern

bearing indicator panel.

The observational accuracy in direction finding is frequently poor, either because of very low signal strength or because of wildly fluctuating bearing indications.

On a weak signal that is practically lost in the receiver noise level, the propeller tips can become very poorly defined as shown in Fig. 9. A novel feature of this bearing indicator enables the operator to split such an indistinct and noisy indication into a pair of overlapping patterns as shown in Fig. 10. These split patterns have a clearly defined intersection which is relatively free from noise and which corresponds to the bearing. The enhancement of observational accuracy achieved by splitting the indicating pattern is obvious.

Splitting of the indication is accomplished by combining the sensing signal with the directionally-characterized carrier-suppressed signal represented by Eq. 12. This combination of signals causes the envelope minima of the latter signal to become unsymmetrically displaced in time. The rotating diametral line on the indicator screen traces, in each of its revolutions, a complete propeller-shaped pattern corresponding to each of the two envelope minima. The normal indicating pattern shown in Fig. 3 is actually composed of two perfectly superimposed propellers. When the envelope symmetry is destroyed by introducing the sensing carrier signal, the two patterns are displaced from the normal angular position of the pattern by equal amounts in opposite directions, thus resulting in split patterns as shown in Fig. 10 and Fig. 11.

A symmetrically split pattern, such as is shown in Fig. 11, can be produced only when fairly ideal conditions prevail in the wavefront of the received signal. When certain troublesome fine-structure diversity effects exist in the received wavefront, an unsymmetrically split pattern as illustrated in Fig. 12 is obtained.

On wildly fluctuating bearings, the degree of dissymmetry is constantly changing and the operator records bearing observations at the moments when the pattern becomes symmetrically split. The splitting feature, therefore, serves as a means of evaluating the accuracy of observations.

Multiple Operation

It is frequently necessary or desirable to obtain bearings simultaneously on a number of signal sources. For example, in the administrative control of aircraft flights several dispatchers may require individual direction-finding facilities. The output from the electronic goniometer described here consists of an entire spectrum of carrier-suppressed signals, each having a directionally characterized envelope phase. A single antenna system may, therefore, be connected to any desired number of receivers and bearing indicators. The receivers and indicators may be installed in different rooms or buildings to permit simultaneous direction finding, without interaction, for any desired number of signal sources.

For aircraft navigation, rescue operations, and the location of illicit transmitters, several direction finders are operated on baselines, and position fixes on radio transmitters are found by triangulation. In such cases, the bearings observed at the individual direction finders are relayed to a central point for plotting. In aircraft homing a reciprocal bearing is relayed to an aircraft.

The bearing data are usually relayed by code or voice over a telephone line or a radio circuit. This procedure is often both time-consuming and inaccurate. To overcome this difficulty, automatic telemetering arrangements have been devised by means of which both the directionally characterized envelope from the receiver and the phase-reference signal from the low-frequency oscillator can be relayed directly to a remote indicator over any two-terminal communication circuit. Bearing data, from several ground-based direction finding stations, can thereby be presented continuously in plotting centers or in aircraft.

VHF Applications

Direction finders employing a scaled-down version of the antenna system described here have been built and are now in operation over the frequency range of 100 to 160 mc. The electronic goniometer principle of operation has proved particularly advantageous in this vhf frequency range, as coupling losses are considerably less than those encountered with mechanically-rotated capacitive or inductive goniometers.

The bearing-splitting feature has also proved extremely useful at the higher frequencies where the problem of achieving adequate sensitivity is particularly severe because of low antenna-pickup factors. This feature increases the observational accuracy of the bearing presentation and also increases the total signal sensitivity of the system by making the sensing signal constantly available.

References

(1) Giltner Twist, Army Radio D-F Networks, ELECTRONICS, p 118, Nov. 1944.
(2) Joseph Valasek, "Elements of Optics," 1st ed, McGraw-Hill Book Co., N. Y., p 149, 1928.

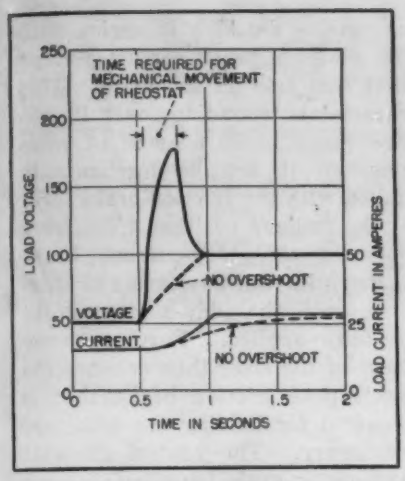

FIG. 1—Solid curves show how voltage overshoot counteracts inductive lag

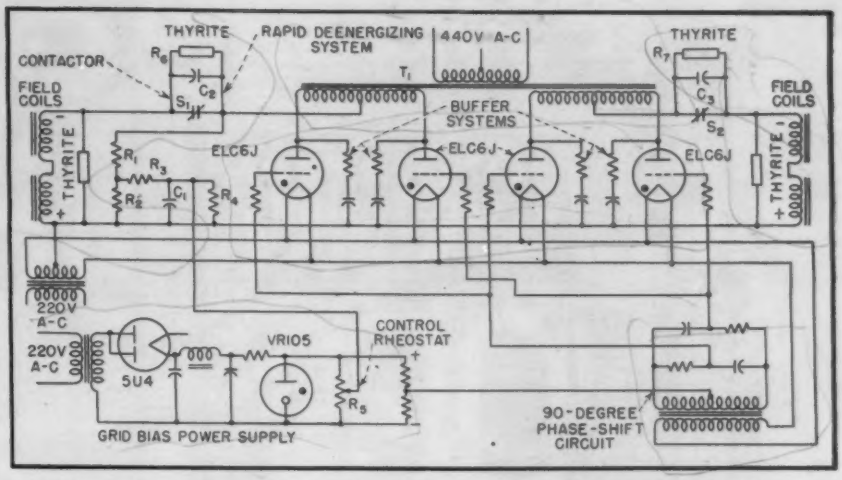

FIG. 2—Control circuit used to supply variable value of direct current to field coils of eddy-current brake. The four type ELC6J tubes are xenon-filled thyratrons

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Electronic equipment performs reliably as source of direct current for eddy-current brake despite rough handling and exposure to water and desert sun. Xenon-filled tubes contribute to success of circuit used

for Oil Drilling Rigs

lowered into the hole. The total energy absorbed during each braking to a stop is variable, depending on the depth of the hole and the weight of the pipe. Application of the brake must be precise and rapid. One slip might cost a man's life, destroy an investment of a million dollars, or result in many delays. The number of braking steps must be infinite so that smooth deceleration of the string of pipe is obtained.

Eddy-Current Brake

The eddy-current brake decelerates the load smoothly, without shock to the mechanical system, and decreases the speed of the pipe to a slow and safe value in a very short period of time. A solid magnetic-alloy rotor is mounted on a shaft that is directly coupled to the drawworks drum shaft. Acting on this rotor are four stationary field coils carrying direct current furnished by the electronic control unit. Eddy currents generated in the moving rotor vary with field excitation. The higher the field current, the higher the braking torque due to eddy currents. The heat energy absorbed by the rotor due to these circulating currents is dissipated in the cooling water that flows through the magnetic air gap and directly onto the rotor's eddy-current surface where the heat is generated.

The field coils surrounded by iron constitute a highly inductive circuit, making the time constant of the electromechanical system high. The time required to apply the brake and deenergize it must be held to a minimum, hence special circuits are required to counteract this inductive lag.

To decrease the time constant while increasing field current, overvoltage is momentarily applied to the field coils. As coil current approaches maximum, the overvoltage is gradually reduced, as indicated in Fig. 1.

Electronic Control Circuit

To deenergize rapidly without allowing inverse voltages to be generated and with decay time at a minimum, a contactor is used in series with each pair of coils. Sufficiently large capacitors are connected across the contacts to allow contacts to open before high arcing voltages appear. To keep at a safe minimum the inverse voltages developed across the coils, a nonlinear resistor (Thyrite) is connected across each pair of coils, as shown in Fig. 2. These limit the inverse voltage to about 1,000 volts. Dis-

Driller at hoisting drum, with right hand on brake lever. Eddy-current brake is at extreme right, in line with shaft of hoisting drum

Thyratron Braking

AS A SOURCE of direct current for the eddy-current brakes used in oil field drilling operations, electronic controls employing thyratron tubes offer reliability, flexibility, low cost, and ease of maintenance, and at the same time permit high operating speeds in the handling of drill pipe.

Any failure in the control system would in most cases cause shutdown of the drilling rig. The cost for a drilling operation is high, usually about $1,500 per hour, so that even a one or two hour shutdown would be serious. The design of the electronic control must therefore be simple, with a minimum number of components, for reliable service. In the event of a failure, the circuit should fail safe (with maximum d-c output). Also, in the event of a tube failure, at least partial power output must be maintained so that the drilling operation may continue.

All control equipment must be designed to withstand the elements, since the control itself is usually out in the open. Cabinet openings must be screened so that rattlesnakes, tarantula spiders, and other pests cannot enter.

All control equipment is anchored to the quarter-inch thick steel plates of the cabinet with rubber shock mounts, since unloading sometimes involves shoving the equipment off the back end of a truck for a four or five-foot drop to the ground.

Braking Problem

The oil-well drawworks consist mainly of a suitable power plant, such as a 1,000-hp steam engine, diesel engine, or diesel-electric combination, a means of changing the gear ratio for hoisting or lowering, a method of clutching the hoisting drive to the power takeoff, and a method of holding the load that is connected to the end of the line. An eddy-current brake cannot hold the load absolutely stationary, and therefore an additional friction brake is required for holding. The eddy-current brake must momentarily absorb as much as 5,000 hp for stopping or slowing down the load of drill pipe or casing.

Drill pipe is lowered in sections of 90 or 120 feet. After a dull drill has been pulled up and replaced, a section of drill pipe is placed in the hole. A second section is then connected to the first and slowly lowered into the hole by the drawworks. This process continues for perhaps eight hours until the entire string of pipe, which can be as much as 15,000 feet, has been

High Altitude Tube

Anticorona base makes an airtight fit in a molded socket. By thus excluding air from around base pins, tube can be operated at full rating in guided missiles flying at altitudes higher than ten miles and in industrial equipment subject to dust, moisture and fumes

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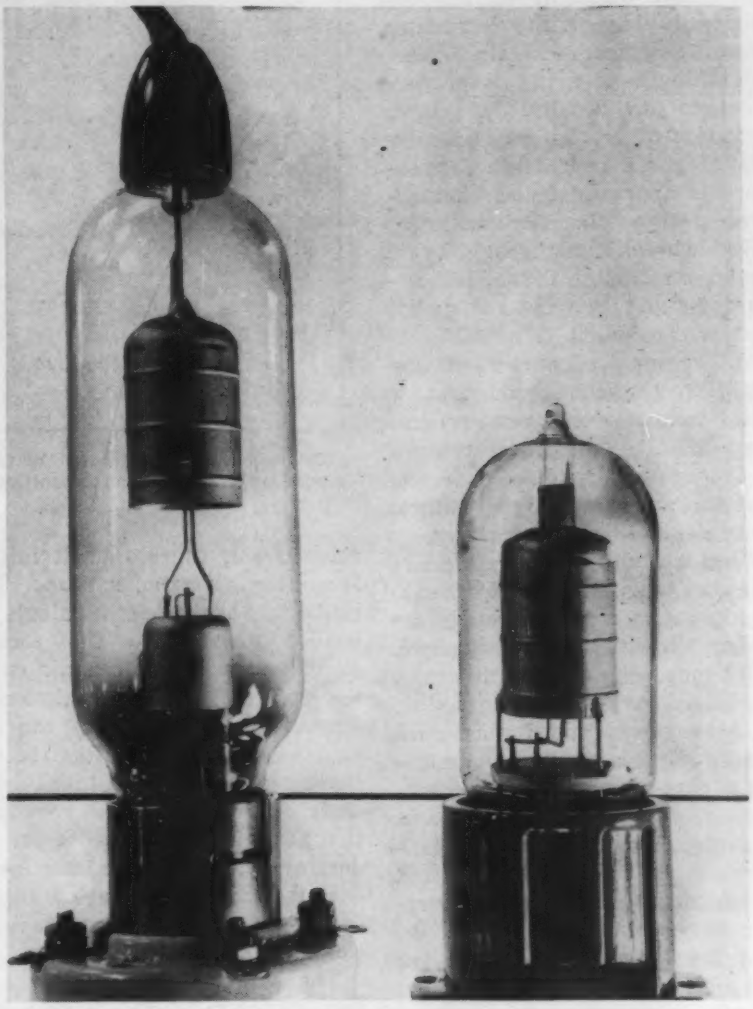
EQUIPMENT operating at high altitude or low pressure must be designed with special attention to corona and high-voltage breakdown. A high-vacuum half-wave rectifier rated at 14,000 volts peak inverse and capable of delivering an average plate current of 125 ma has been developed for use in such equipment.

As the accompanying photograph shows, the anticorona tube and its associated socket are only about half the size of a conventional tube having the same ratings at sea level. The anticorona tube operates with full rating at an altitude of 60,000 feet (at which the pressure is about 2 in. of mercury and the temperature is about −55 F).

The tube has been developed under the auspices of the Air Materiel Command of the Army Air Forces to meet requirements for electronic controls in guided missiles and jet-propelled airplanes that reach high into the troposphere. However, its construction suits it for use in industrial installations where protection from dust, moisture, vibration, and shock are essential. Before describing the tube, it is advisable to review the considerations by which it was designed.

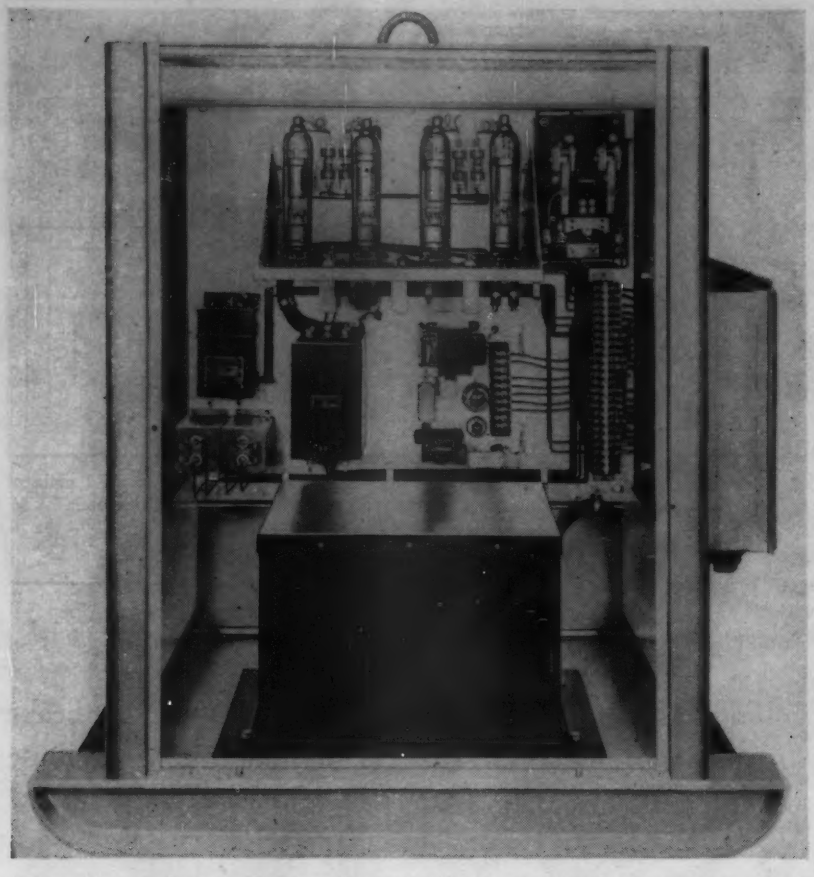


Conventional tube (left) must be conservatively operated at high altitudes or in contaminating atmosphere, while new tube (right) having comparable characteristics and with pins completely enclosed can be operated at full rating

Breakdown Considerations

Conventional high-voltage tubes designed to operate at sea level can not be operated at their full ratings at high altitudes. For example, with a typical pin spacing of 0.75 in. and a pin diameter of 0.125 in., a tube base can withstand in excess of 10,000 volts at sea level, but will break down at 2,000 volts at an altitude of 60,000 feet.

In addition to the high-voltage problem, there is that of continuous temperature variation. Unless the equipment compartment of an airplane is heated, the electronic equipment in a plane flying at high altitude will be cooled to a low temperature. When the plane decends, it usually passes through warm air. Moisture in the warm air condenses on the cooler members of the plane, freezing in some circumstances. Under such conditions, a direct water path is formed between tube



Electronic control unit for 5,000-hp eddy-current brake, with front cover removed. Cabinet is made from quarter-inch steel plate to withstand rough handling in oil fields

sipation of the inductive energy in this manner results in a decay time constant of 0.002 second.

Since electronic controls of this type must operate in any climate, in temperatures ranging from — 20 F to 110 F, mercury-vapor tubes were out of the question without auxiliary heating devices. Xenon-filled grid-controlled rectifiers are being used with considerable success. Extreme temperature variations have little effect on the critical grid-firing points. It is necessary, however, to add an R-C buffer system between the plate and cathode of each tube. The weight of xenon molecules is much less than that of mercury molecules, hence the xenon molecule can accurately follow high rates of commutation and destroy tube characteristics. The R-C buffers keep commutation rates at a safe value.

Since the atmosphere surrounding this control system involves a wide variety of climatic conditions and may be explosive, all components must be hermetically sealed.

In some cases the power supply at a drilling site is a gasoline-driven motor-generator set whose output voltage may range from 180 to 260 volts. A voltage-regulating filament transformer is therefore used to stabilize heater voltages, and a V-R tube is used in the grid-bias reference supply.

The circuit of the electronic power supply for the eddy-current brake is fundamentally simple, its design being based primarily on reliability gained from experience. The two secondaries of power transformer T_1 supply two conventional full-wave rectifier circuits connected in the same phase relationship so that the grids for each phase may be connected together. With this arrangement, failure of a rectifier tube in either half of the system will not cause a complete power failure.

Brake Control Rheostat

Rheostat R_5 controls the current output to all fields by introducing a variable d-c bias in series with the a-c phase-shift circuit voltage that also acts on the grids. This rheostat is wound to cover its entire range in 90 degrees of rotation, so it can be mechanically linked with the friction-brake lever at the driller's position. The lever operates the eddy-current brake through its first 90 degrees of traverse, until the eddy-current brake is fully applied. Further movement of the lever then engages the mechanical friction brake that is required for holding the drill pipe stationary. The control rheostat housing is explosion-proof.

The phase-shift circuit provides 90-degree out-of-phase a-c voltages that can be shifted above and below the reference axis by varying the d-c bias introduced by control rheostat R_5, thereby permitting smooth control of thyratron output current by varying the fraction of each cycle during which each thyratron is conductive.

The return path from the movable arm of R_5 to the cathodes is through a degenerative time-delay circuit that provides voltage overshoot. The voltage output from one pair of gaseous rectifiers is voltage-divided by R_1 and R_2. A voltage proportional to that applied to the field coils appears across R_2 and acts on the combination of R_3 and C_1, which represents a time delay equal to that of the inductive load. This time-delay circuit causes the voltage applied to the field coils to overshoot during the charging time, making the charging action as fast as is possible with the voltage available to the field.

Contactors S_1 and S_2 interrupt the field circuits when R_5 is turned toward zero, so as to obtain rapid decay of the inductive load. Capacitors C_2 and C_3 are placed across the contacts to eliminate arcing, with Thyrite resistors R_6 and R_7 across the capacitors to protect them from high-voltage surges.

Bibliography

(1) R. L. Jaeschke, Electronic Control for Magnetic Clutches, ELECTRONICS, p 102, Aug. 1945.

(2) D. L. Greene and R. L. Jaeschke, Reliable Electronic Controls for Fan and Stoker Drives, *Electrical World*, p 75, Nov. 23, 1946, and p 96, Dec. 7, 1946.

(3) A. E. Woolen, Experience with Electrical Eddy Current Rotary Brake, *American Petroleum Institute*, paper No. 801-221.

base pins, and may result in electrical breakdown if the water dissolves impurities that cause it to become conductive.

The tube must also withstand a temperature range of −55 C to +250 C, a rate of temperature change as high as 1 C per second, and be rugged enough to withstand mechanical shock and vibration imposed on it by the tremendous rates of acceleration of the missiles and planes in which it is used. These mechanical requirements prohibit solving the voltage breakdown problem by simply increasing pin spacing and tube size.

Dielectric strength of air decreases rapidly with decreasing pressure; or more exactly, dielectric strength of a gas is proportional to its density. At best, prediction of breakdown in a mixture of gases such as the atmosphere is approximate, so that accurate design is not feasible.

Beside breakdown through the air breakdown through the solid dielectrics of the tube base and socket must be considered. In solid dielectrics, rupture occurs when the potential gradient throughout a finite volume exceeds a critical value called the dielectric strength of the material. This dielectric strength varies with temperature, thickness, and moisture content.

When two adjacent dielectrics are subjected to an electric field, breakdown usually occurs through the weaker dielectric. For example, with bonded glass-mica adjacent to air, breakdown occurs in the air at the surface bonded glass-mica because there is greater concentration of flux there than in the adjacent air. This non-uniform field at the surface between adjacent dielectrics is usually further aggravated by additional field distortion resulting from imbedded terminals. Also, the intense fields associated with high-voltage tubes attract dust and other particles to the surfaces of the tubes. This dirt and condensed moisture pass creepage currents which tend to lower the breakdown voltage.

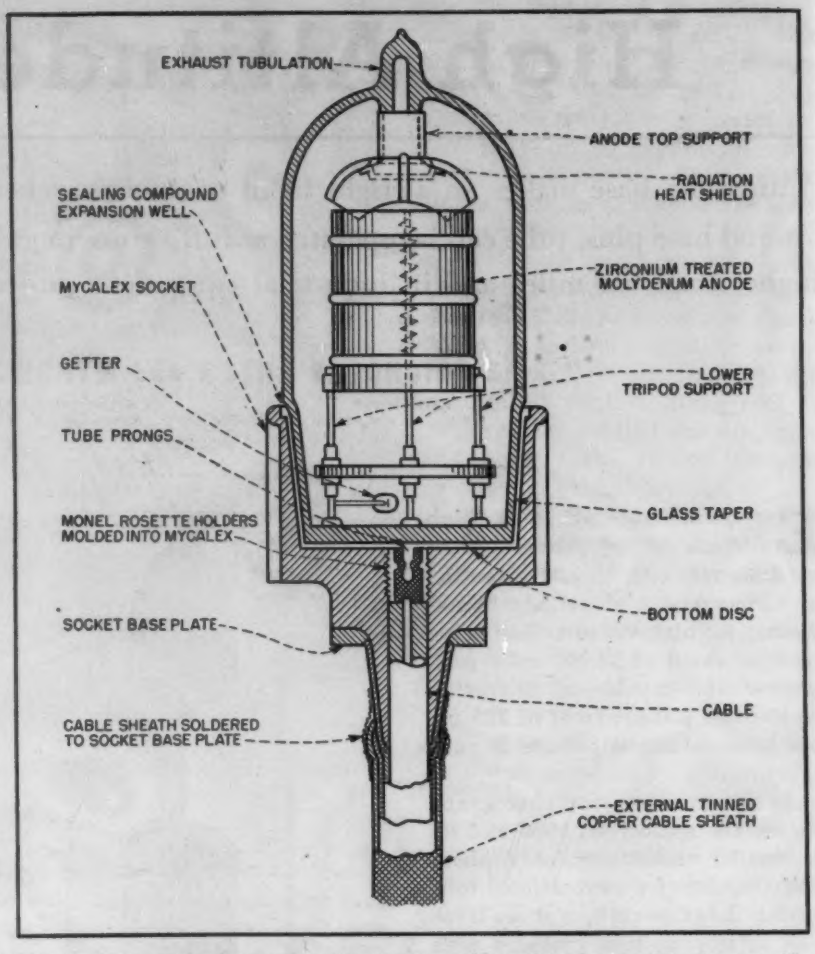


FIG. 1—Constructional features of anticorona tube and socket combination provide ruggedness and air-free pin connections. Base and socket are made to same tolerances

Base and Socket

To prevent voltage breakdown, the tube base and socket were designed to exclude air from the connection. As shown in Fig. 1, the tube base is tapered to fit into a socket having a similar shape. The cable to the socket terminals is bonded directly to the socket, so that at no point can air enter the system. Thus the insulation is directly under control of the design engineer. In addition to excluding air which could break down under voltage stress, this construction also prevents corrosive fumes, dust, and moisture from interfering with the circuit. The tube is therefore well suited to use in industrial equipment.

The taper angle is large enough so that air is not trapped when the tube is inserted in the socket. Figure 2 shows details of base and socket construction and illustrates how air escapes until the tube base reaches the very bottom of the socket. To insure complete exclusion of air between the tube and socket, and also to prevent binding, a viscous silicone oil (viscosity in excess of 900,000 centistokes—slightly more viscous than vaseline) is applied in a thin layer to the tube base and to the inside of the socket before inserting the tube. (If too thick a coating is applied, the air can not escape from under the tube, preventing it from seating properly, and will tend to push the tube out of the socket.) This oil does not deteriorate, undergo change in viscosity, nor lose its dielectric strength throughout the temperature range from −60 to +400 F and is impervious to water or ice. The tube terminals are therefore surrounded by dielectrics of high electrical strength that are unaffected by variations of temperature, air pressure, or humidity.

A gradual but firm outward pull on the tube separates it from the socket. Because all tapers on tubes and sockets are precision ground, all tubes and sockets are interchangeable.

The tube prongs fit into spring rosettes contained in rosette hold-

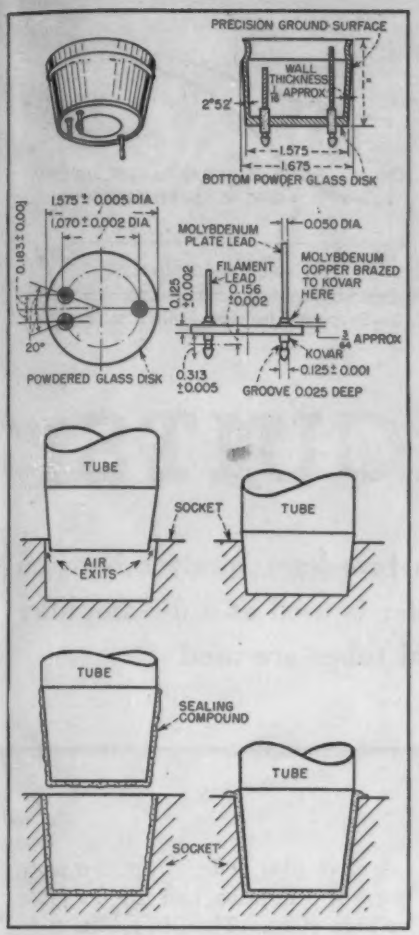


FIG. 2—Details of tapered tube base show how air is excluded from pin connections

ers that are in turn molded directly into the socket. The rosettes engage grooves in the tube pins and thus make good electrical contact to them. Bonded glass-mica is used for the socket material because it will not carbonize in the event of an electrical breakdown as would most synthetic resins. Thus a flashover will not permanently damage the socket. In addition, this material is closely akin to glass so that the base and socket have comparable dimensional stabilities. It can be molded and ground to the required close tolerances.

Because the socket and cable completely enclose the high-voltage conductors, the system is shockproof. The cable sheaths and socket base plate are interconnected and grounded.

Electrical Characteristics

The tube itself is a high-vacuum half-wave rectifier rated at 14,000 volts peak inverse. It can deliver an average plate current of 125 ma and a peak plate current of 750 ma. The voltage drop of the tube is 200 volts at 100 ma, and its anode is capable of an average dissipation of 75 watts. The thoriated filament is rated at 5 volts, 6 amps. When the tube is pulsed at 4,000 volts peak, the filament will supply in excess of 2 amperes of useful peak emission. All of these ratings are applicable at any altitude up to 60,000 feet. The tube is only 4.37 in. long and 1.75 in. in diameter. Of this length, approximately 3.25 in. protrudes above the top of the socket. A typical conventional tube having approximately the same electrical ratings, but at sea level only, is over 8 in. long and of comparable diameter.

Mechanical Construction

The anode is fabricated of molybdenum sheet and coated with zirconium to provide continuous gettering action in addition to the regular getter. A standard type getter of iron-clad barium is employed, but is enclosed in a mesh trap that prevents the active material from migrating to other portions of the tube. The envelope is hard glass so that it can withstand continuous operation at 400 F. The tube and socket assembly is capable of withstanding voltages as high as 35,000 volts peak.

Ruggedization has been given special consideration in the design. The short length of the tube enables it to better withstand impact because of the reduced moment acting on the anode. In addition, the anode is supported at its lower end by a tripod and at its upper end by a heavy glass exhaust tubulation. To protect this glass support from direct thermal radiation from the filament, a molybdenum heat shield has been welded to the anode.

Production Processes

Although these innovations in tube design are fairly simple, several new assembly techniques were required to maintain tolerances of taper and pin position. To produce accurately the glass discs bearing three terminals that are properly located and vacuum sealed, powdered glass techniques are used. Molds of material whose coefficient of expansion matches that of the glass were designed and accurately machined so as not to warp when subjected to the approximately 1,000 C temperature necessary for melting the glass.

The rods of either molybdenum or Kovar are inserted into the mold. A measured quantity of carefully sifted and washed powdered glass is spread into the cavity of the mold. The mold is then heated by induction and the glass properly fused. In this way the rods are sealed into the glass disc in perfect alignment.

The glass disc produced by this technique is not transparent; it is filled with millions of very small and very uniformly distributed bubbles. The bubbles do not appreciably affect the electrical strength of the glass. On the other hand, they increase the resistance of the glass to thermal shock, thus enabling it to withstand temporary strains induced by large temperature gradients.

The second step in fabricating the tube is to join the molded disc in which the pins are sealed to the glass taper without distorting the work or requiring excessive grinding of the finished assembly. Ordinary sealing methods produce more distortion than the tube design can tolerate. However, molds can again be used. One mold was designed to be affixed to the tail stock and the other to the head stock of a horizontal glass lathe. A piece of glass tubing that has been approximately shaped to the profile of the taper is held in one mold and the molded glass disc in the other, and the two parts fused by conventional methods. While the assembly is still plastic, the mold is closed and the glass pressed into the exact shape of the finished taper. This procedure insures alignment of the pins with the axes of the taper. The finished base is shaped on a precision grinder to the final tolerances of ±0.002 inch.

The taper assembly is over an inch deep. In order to weld the tube components into it, a series of offset points for spot welding are required. Therefore, in addition to designing the tube components to meet electronic requirements, they have been designed to make mass production possible.

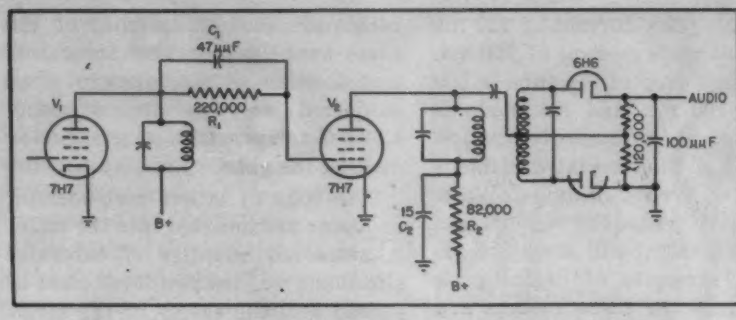


FIG. 1—A direct-coupled cascade limiter wired for partial squelch

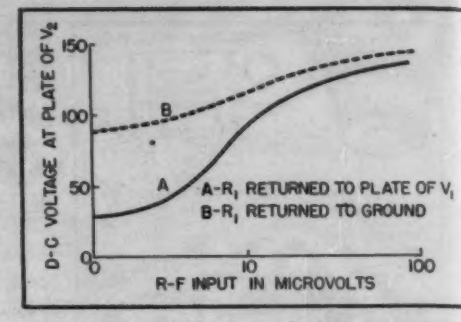


FIG. 2—Response for two limiter connections

SQUELCH CIRCUITS

Simple circuits for disabling the audio amplifier of an f-m broadcast receiver between stations. In several arrangements described the second limiter is used as a d-c amplifier for supplying squelch voltage and no additional tubes are used

SQUELCH CIRCUITS for disabling the audio amplifier in the absence of a received carrier have been used for some years in f-m communications receivers, where intermittent operation makes their use imperative. Noise output of an f-m receiver without an incoming carrier is relatively great owing to high i-f gain and the fact that the amplitude limiter becomes an efficient amplifier for receiver noise.

A common squelch method is to bias the first audio tube beyond plate current cutoff, using a control voltage derived from the i-f amplifier or detector. The additional amplifier required has generally been an economic impediment to the use of such circuits in f-m broadcast receivers.

No Extra Tubes

Several squelch circuits to be described provide adequate action without additional tubes if the receiver employs a genuine amplitude limiter.

Historically, the first form of such circuits[1] was used in prewar Zenith f-m receivers as shown in Fig. 1. Tubes V_1 and V_2 constitute a cascade limiter in which the signal from the i-f amplifier is clipped on one side by V_1 and on the other side by V_2. This circuit is like that of any other cascade limiter, except for the positive bias on the grid of V_2 arising from the connection to $B+$ through R_1. The positive bias, in combination with the poor regulation of the plate circuit, owing to R_2, greatly reduces audio noise in the absence of a signal resulting in a partial squelch action while tuning between stations.

The solid line (A) of Fig. 2 shows the plate voltage of V_2 as a function of signal input with R_1 connected to B+, while the dotted line (B) shows the plate voltage with R_1 grounded. The effect of the positive bias is to increase the plate current of V_2 for low signal levels, thus dropping the plate voltage to a point below the knee of the e_p, $-i_p$ curves for a pentode. In this region the g_m of the tube is low, and the plate resistance is greatly reduced. These two effects combine to reduce the noise output of the discriminator. In addition, the grid-cathode impedance of V_2 is lowered due to the positive bias, decreasing the noise response of the tuned input circuit. As the desired signal increases, a negative bias is built up, the plate current decreases, and the d-c plate voltage rises. Thus in addition to its r-f limiting action the tube acts as a d-c amplifier with the rectified signal voltage as a d-c input.

Since the plate voltage change over the desired signal range is of the order of fifty volts, it is an easy matter to use this potential to disable the audio amplifier. Figure 3 shows the circuit used to disable a first audio stage consisting of a zero-bias high-mu triode.

The control voltage appearing across R_2 is divided by five through R_3 and R_4, and applied to the lower end of the audio grid resistor R_5. The cathode of the audio tube is biased positively by the divider R_6 and R_7. The cathode bias is adjustable and is set so that the audio grid is biased beyond plate current cutoff in the absence of a signal. When a signal is applied, the positive voltage across R_3 and R_4 is increased and the tube resumes normal operation.

Bypassing capacitors C_3, C_5, and C_4 are required to keep residual noise and hum off the audio grid. The time constant of R_5 and C_5 should be small enough so that the

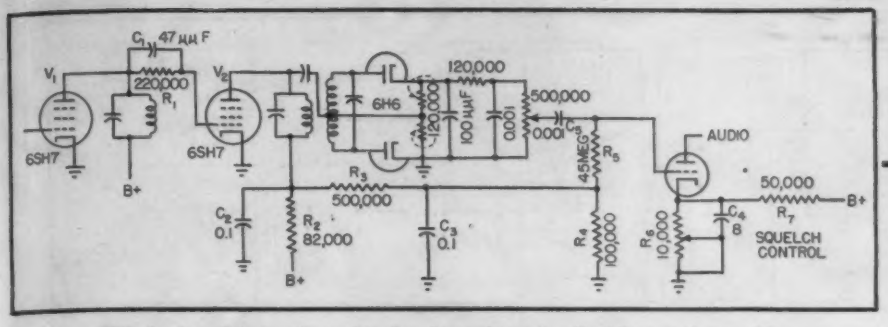


FIG. 3—Squelch circuit used to develop voltage for disabling audio amplifier

for F-M RECEIVERS

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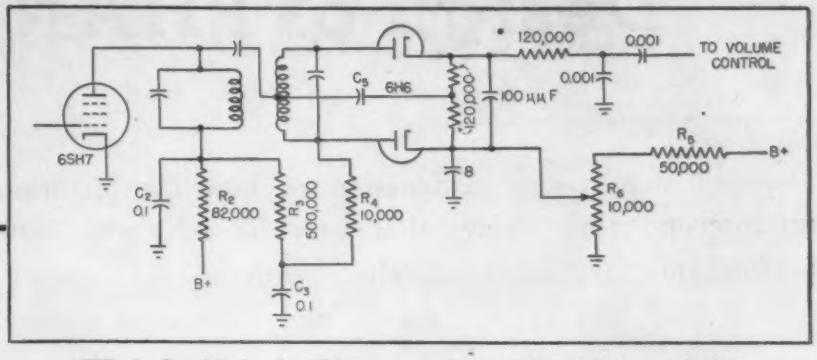

FIG. 4—Squelch developed by means of bias on the discriminator diodes

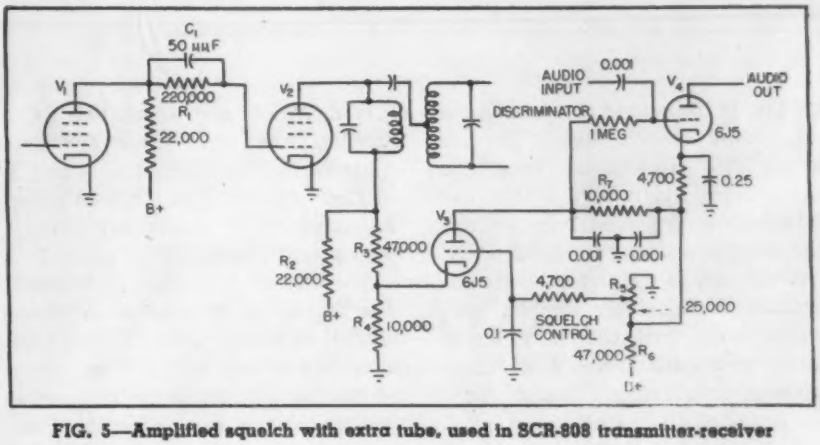

FIG. 5—Amplified squelch with extra tube, used in SCR-808 transmitter-receiver

control voltage can respond to the average tuning rate. If this time constant is too large, it is possible to tune through a station before the squelch action ceases. To prevent the grid from going too far positive, R_5 is made large, at least 30 megohms. With the grid too positive and too small a coupling capacitance, some low frequency response is lost, owing to the decrease in grid-to-cathode impedance.

The squelch voltage can also be applied directly to the diode detectors, as shown in Fig. 4. Both diode cathodes are biased positively through the divider and squelch control R_5 and R_6, while the control voltage is applied without reduction to both diode plates through R_4. The diode plates are isolated from the cathodes for d-c by C_3. Adequate for communications service, this arrangement is not as satisfactory as the previous one for broadcast use because the audio level at the detectors is high. When tuning off a station some distortion results before suppression is complete.

Amplified Squelch

When the utmost in performance and ease of control is desired a single d-c amplifier can be added. In Fig 5 voltage across the second limiter plate resistor is taken from the divider R_2, R_4, and applied to the cathode of the d-c amplifier V_3. The grid of this tube is supplied with a variable positive bias from a potentiometer across the B supply. In the absence of signal, the grid is positive with respect to the cathode, and the tube draws full current. The resulting voltage drop across R_7 is applied to the grid of the first audio tube V_4, to cut off plate current. With a signal applied, the second limiter plate current is reduced, and the cathode of V_3 rises in potential respect to the grid, cutting off the plate current of this tube. This action in turn removes the bias from the first audio tube.

Reference

(1) U. S. Pat. 2,323,880, issued to C. W. Carnahan.

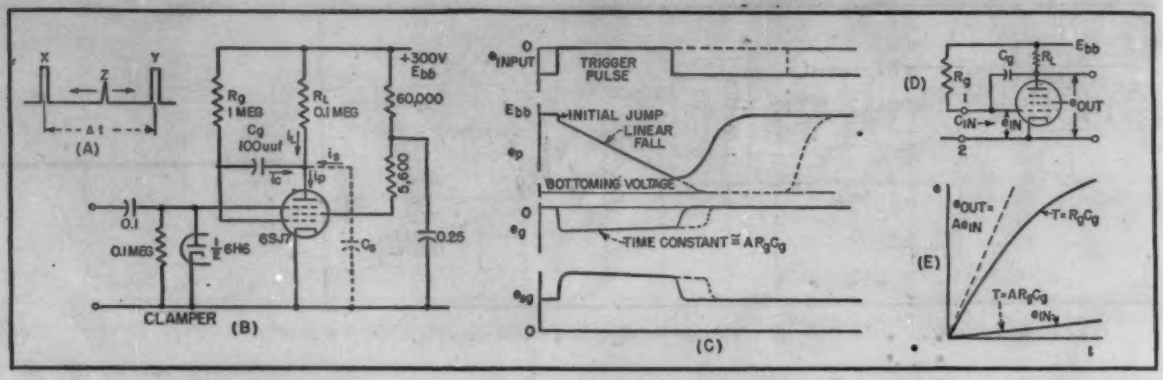

FIG. 1—In waveform A, a phantastron triggered by pulse X produces a controlled-position marker pulse Z. To measure time delay, phantastron control voltage is set so pulse Z coincides with Y. Other diagrams here apply to the Miller circuit

Design of PHANTASTRON

Detailed step-by-step explanation of how the phantastron circuit provides precision microsecond time delays that vary linearly with control voltage. Factors affecting performance are analyzed, along with use of control circuits, cascading for longer delays, and calibration techniques

THE phantastron is a simple electronic circuit which produces a variable time delay free from short-time jitter and stable over relatively long periods. In addition, the delay is a linear function of control voltage, so that an accurate calibration is relatively simple. In a particular circuit, the ratio of maximum to minimum delay attainable without sacrificing linearity is of the order of 50 to 1.

The need for time-delay circuits has become of importance in the past few years with the increasing applications of radar and of pulse-type navigational aids. In these systems, measurement of time intervals to a high order of accuracy is required, and a circuit such as the phantastron is extremely useful for such purposes.

A simple example will serve to illustrate the use of a time-delay device. Assume two pulses are received which are separated by a time interval Δt. These are presented on an oscilloscope as X and Y in Fig. 1A. The first received pulse, X, triggers a time-delay circuit which produces a marker pulse Z at a controllable time after triggering. The marker pulse may be adjusted until it coincides with Y. The time interval between X and Y may then be read as a function of the control voltage on the delay circuit. Control voltage can be obtained from a potentiometer, calibrated to read Δt directly.

A single-shot multivibrator with an adjustable width of pulse may be used as a time delay with the first signal initiating the action, and the trailing edge of the multivibrator output being used to develop a marker. The width of the pulse may be controlled readily and so a delay time may be introduced. This delay multivibrator[1,2] is simple and the delay is roughly linear with the setting of a linear potentiometer over a wide range. However its deviations from linearity (several percent) and short-time instability (of the order of 0.5 percent) are definite limitations in applications where high accuracies are involved. The phantastron, on the other hand, can be made linear to about 0.1 percent of maximum delay and has a short-time jitter of less than 0.05 percent.[2,3] Other circuits, such as the bootstrap sweep circuit with a comparator diode, produce results of equal precision, but are considerably less economical in the number of tubes employed.

Miller Sweep Circuit

The heart of the operation of a phantastron lies in the production of a voltage at the plate which decreases linearly with time for almost the entire period after the

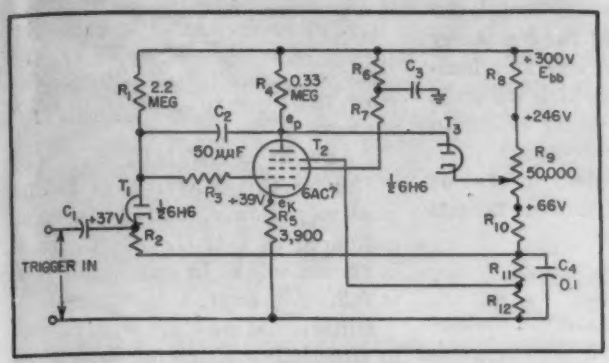

FIG. 2—Simple pentode phantastron circuit as developed in England

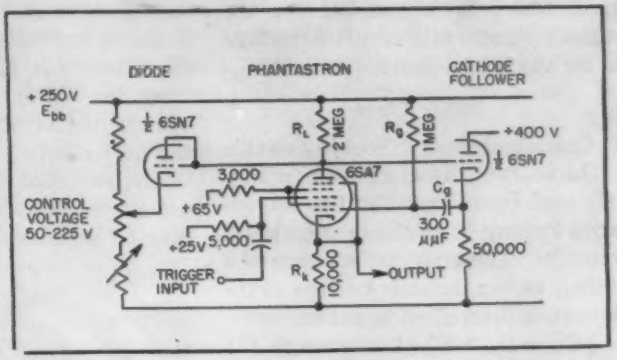

FIG. 3—Pentagrid converter adaptation of phantastron, with cathode follower

TIME DELAY CIRCUITS

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and MATTHEW T. LEBENBAUM

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BACKGROUND

Developed in British and American laboratories for wartime application to radar equipment, the phantastron circuit is widely used today in a host of military, navigation, and industrial applications, yet is still one of the most misunderstood circuits in the electronic field. Designers know it works, but up to now there has been no detailed explanation of exactly what goes on in the six stages of its operation

initiating trigger. To understand the mechanism of this linear variation, it is useful to analyze in some detail another circuit, the so-called Miller fed-back time base. This circuit, shown in Fig. 1B, can produce an extremely linear time base.

In the quiescent condition, the suppressor is sufficiently negative to cut off plate current. The grid is at zero because of the positive grid return. Except for a very small grid current, all of the space current goes to the screen.

If the suppressor is suddenly brought up to zero by the trigger, the time base is initiated. The circuit wave forms are shown in Fig. 1C. The solid lines are for the case of plate current cutoff before the plate has bottomed (see the following discussion); the dotted lines are for termination of the time base after bottoming.

The plate current is the sum of the three currents shown in Fig. 1B: the discharging current i, from the stray capacitances, the discharging current i_c from C_g, and the current i_L through the load resistance. When the suppressor is brought up to zero, a large fraction of the space current must flow to the plate as in a normal pentode. Since the grid side of C_g is tied to B+ through the large grid resistor R_g, the discharging current from C_g will be limited to approximately E_{bb}/R_g.

At the first instant, the strays supply most of the plate current, which is fairly large since the tube was operating at zero grid bias before the trigger.

As the strays discharge, the plate voltage drops and current flows through R_L. This drop is transmitted to the grid, since the voltage across C_g cannot change rapidly. As a result, space current is reduced. Since the plate can only fall a few volts before the tube is cut off, and because R_L is quite large, i_L will be small.

An equilibrium point is soon reached where the plate current is the normal fraction of the existing space current, and the fall of plate voltage is arrested.

Actually, the plate voltage continues to fall, as is shown below, but the rate of change of grid voltage goes through zero and becomes positive as C_g discharges through R_g. This occurs when the rate of fall of plate voltage is exactly equal to the rate of change of voltage across C_g. As the grid rises and space current increases, the plate current also increases and the plate voltage continues to drop, but at a slower rate. This drop, reflected to the grid through C_g, retards the rise of grid voltage. It is this feedback

path which is responsible for the almost linear fall of plate voltage after the initial jump.

Miller Effect

One simple way of looking at this is to redraw the circuit as in Fig. 1D and consider what the impedance looking in at the terminals 1-2 must be. The input capacitance of a tube, as expressed by the well-known Miller effect equation, is

$$C_{in} = C_{gk} + C_{gp}(1 + A\cos\theta) \quad (1)$$

where C_{gk} is the grid-cathode capacitance, C_{gp} is the grid-plate capacitance, A is the gain of the tube and $\cos\theta$ is the phase angle of the load (unity for a resistance load).

Normally, C_{gp} is extremely small in a pentode, but in this circuit we have deliberately added a capacitance between plate and grid. Since $A >> 1$, the capacitance appearing across terminals 1-2 will be very closely $A \times C_{gp}$. We have, therefore, an RC sweep generator with an extremely long time-constant, and we use only a very small portion of the exponential rise in voltage across C_{in} as the input voltage. This portion is so small that it has a practically linear variation with time.

Figure 1E shows the relative shapes of the voltages. The exponential curve with time-constant of R_gC_g would be the input voltage if C_g were connected from grid to ground. With the grid-to-plate connection, the input voltage rise has a time constant of $A \times R_gC_g$. The output voltage is simply e_{in} times the gain.

More formally, one may express the rate of change of plate voltage mathematically. This is useful, for it shows immediately the necessary conditions for linearity, and indicates the region in which we must operate the tube in order to obtain the best results.

The variation in plate current of a pentode for small grid variations may be expressed as

$$i_p = g_m\left(e_g + \frac{e_{sg}}{\mu_{sg}} + \frac{e_p}{\mu_p}\right) \quad (2)$$

where e_g, e_{sg}, and e_p are the instantaneous control grid, screen grid, and plate potentials, μ_{sg} and μ_p are the screen grid and plate amplification factors respectively, and g_m is the plate-control grid transconductance. If we let v_c be the voltage across C_g at any instant, then from Eq. 2

$$i_p = g_m\left[(E_{bb} - R_Li_L - v_c) + \frac{e_{sg}}{\mu_{sg}} + \frac{E_{bb} - R_Li_L}{\mu_p}\right] \quad (3)$$

Solving for i_L and noting that $i_p = i_L + i_c + i_{sg}$, we obtain

$$i_L = \frac{g_m\left(E_{bb} - v_c + \frac{e_{sg}}{\mu_{sg}} + \frac{E_{bb}}{\mu_p}\right) - i_c - i_{sg}}{1 + g_mR_L + g_mR_L/\mu_p} \quad (4)$$

In order that di_L/dt (and therefore de_p/dt) be constant, each term of the denominator of Eq. 4 must be constant and the terms of the numerator must be constant or vary linearly with time. Since R_L is large and only a small grid change is required to produce a large output voltage, if operation is above the knee of the e_pi_p characteristic of the tube, g_m, μ_p, e_{sg} and μ_{sg} are relatively constant. The current i_c flowing into C_g is $(E_{bb} - e_g)/R_g$, and since the change of e_g is small compared to E_{bb}, to a high degree of accuracy i_c is a constant, as follows

$$i_c = \frac{E_{bb} - e_{grv}}{R_g} = \frac{E_{bb}'}{R_g} \quad (5)$$

Now, $dv_c/dt = i_c/C_g$, so from Eq. 5 we have

$$dv_c/dt = E_{bb}'/R_gC_g \quad (6)$$

During this stage, e_p is falling relatively slowly, and i_c is small compared to i_c if $C_g >> C_{gp}$, as it is chosen to be. In any event, if e_p is falling linearly, i_c is constant.

Differentiating Eq. 4 with respect to time and multiplying both sides by R_L, we obtain

$$R_L\frac{di_L}{dt} = \frac{de_p}{dt} = -\frac{g_mR_L}{1 + g_mR_L(1 + 1/\mu_p)}\frac{E_{bb}'}{R_gC_g} \quad (7)$$

Making the further assumption that $\mu_p >> 1$ and $g_mR_L >> 1$, Eq. 7 reduces to

$$de_p/dt = -E_{bb}'/R_gC_g \quad (8)$$

This indicates that if our assumptions are valid, the fall of plate voltage is linear. The rate of fall is easily calculated from the circuit parameters. In the circuit shown, for example, the fall is approximately $300 \div 10^6 \times 100 \times 10^{-12}$, or 3 volts per microsecond.

Bottoming of Plate

When the plate voltage in the Miller circuit falls to a very low value, our initial assumptions are no longer justified. At low plate voltages, g_m drops rapidly and μ_p approaches 1, and the plate drop departs from linearity. At some point, the rate of change of e_p becomes zero, and the plate is said to have bottomed. This is equivalent to operating below the knee of the pentode characteristic. In this region a

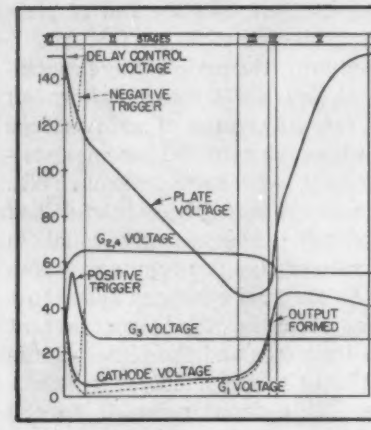


FIG. 4—Phantastron waveforms, divided into six stages according to British custom. Stage VI is quiescent condition

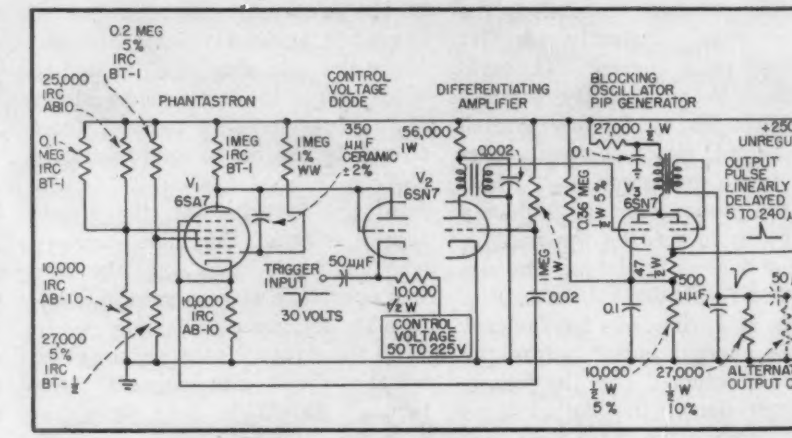


FIG. 5—Phantastron time delay circuit providing 240 microseconds maximum delay. Resistor types specified give the required temperature compensation. Both pulse transformers are Utah X124-T2 or equivalent

drop in plate voltage reduces the fraction of space current flowing to the plate, so that although the total space current is increasing (grid voltage rising), the net plate current change is zero. At this point in the cycle there is no feedback through the plate-grid capacitor, and the grid now rises towards B+ at a rate determined only by the simple time constant, R_gC_p. This increases the total space current and screen current until the grid is caught at zero by the flow of grid current. The initial conditions then exist except that the plate voltage remains almost constant at its bottomed value. In this circuit, the plate can only rise to its initial value if the suppressor grid cuts off the plate current.

If this plate current cutoff could be made to occur when the plate first bottomed, the rise of the grid and screen to their initial values would be greatly accelerated. The increase in plate voltage as plate current is cut off would be reflected back to the grid, greatly increasing the rate of rise of grid voltage. As will be shown later, this can be accomplished simply by use of the phantastron circuit. This sharp rise can then be differentiated and used as an output pulse.

We would then have almost all the elements of a time-delay circuit: (1) A voltage falling linearly with time; (2) A relatively fixed voltage at which the fall is arrested; (3) A method of obtaining a sharply rising voltage at this terminating point for developing into a marker.

If we could control the plate voltage at which the cycle starts, we would have the last element required, for then the total plate voltage drop (and therefore the time) is controllable. There remains only to investigate the linearity of the time delay as a function of the control variable, and the stability of the various stages of the cycle.

Simple Pentode Phantastron

Before this is done, the workings of a simple pentode phantastron circuit will be analyzed in order to draw together the principles discussed above and to indicate wherein it differs from the Miller circuit. The circuit is shown in Fig. 2. Control grid initiation is used instead of suppressor grid triggering. The initial voltages are shown on the schematic, the plate voltage being determined by the setting of R_p. The plate attempts to rise to B+, but when its voltage equals that on the cathode of T_2 (which is variable from 66 to 246 volts), T_2 conducts, catching the plate at that voltage. This is the usual method of controlling the starting voltage of the cycle, and for the values given in this circuit, controls the delay from about 20 to 75 microseconds. Since T_1 is conducting, it holds the phantastron grid at 37 volts. The suppressor is at 20 volts, determined by a bleeder chain; it is almost 20 volts negative with respect to the cathode, cutting off plate current.

Following the British custom, the sequence of phantastron operation will be divided into six stages. The conditions set forth above characterize the quiescent period, stage VI. When a negative trigger of approximately 30 volts peak with a steep leading edge is applied to the grid of T_2 through T_1, stage I is initiated. Since bias resistor R_k is not bypassed, the voltage on the cathode follows the grid voltage as in a cathode follower. Drop in cathode voltage is equivalent to a suppressor voltage rise, and at some point plate current begins to flow. The resulting drop in plate voltage is reflected through C_2 to the grid. This stage will then be recognized as the initial-jump period of the Miller time base. Only one point of difference is important: the grid (and therefore the plate) must fall considerably farther than in the Miller circuit to establish the first equilibrium point because the cathode voltage follows closely the grid voltage, the actual bias developed being equal to $\Delta e_g(1\text{-}A)$ where Δe_g is the change in grid voltage, and A is the gain of the tube as a cathode follower. This initial jump is of the order of 30 to 40 volts, dependent upon the setting of the control voltage.

With plate current equilibrium established, stage II begins. During this stage, the plate voltage drops linearly in exactly the same fashion as in the Miller circuit. It should be noted that T_1 and T_2 are both cut off after the initial trigger by the drop in grid and plate voltage respectively, and are cut off during stages I, II, III, and IV. The tube bottoms at the end of stage II.

Stage III is the period during which the grid voltage rises towards the supply voltage with time constant R_1C_2, as discussed previously. During this stage, the plate current change is practically zero, and plate voltage remains almost constant. As the grid voltage (and therefore, cathode voltage) rises, the suppressor falls with respect to the cathode. The end of stage III is defined as the point where the suppressor voltage has fallen sufficiently to commence cutting off plate current.

During stage IV, the grid rises rapidly, as the plate rise is reflected onto the grid. It is during this stage that the useful output is developed, since the cathode voltage is rising steeply enough to trigger a marker circuit, such as a conventional block-

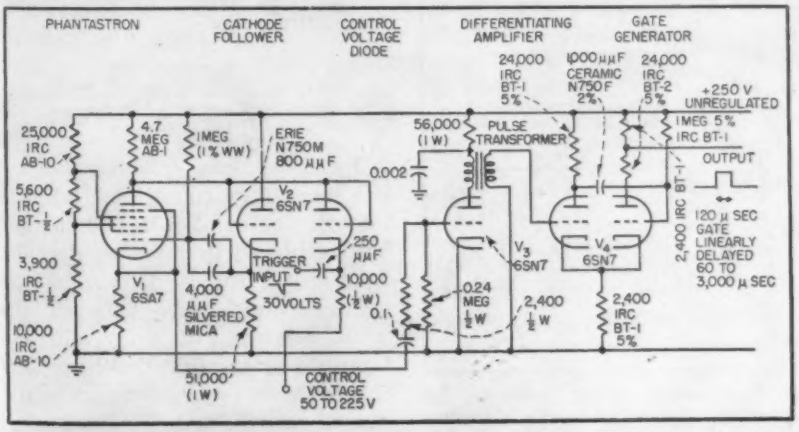


FIG. 6—Phantastron delay circuit with cathode follower and gate output, providing 60 to 3,000 microseconds delay. Pulse transformers are the same type as in the circuit of Fig. 5

Table I—Nonlinearity Errors in 300-Microsecond Phantastron

Cause of Error	Approximate Nonlinearity Introduced
Variation of duration of stage I with control voltage	+0.1%
Variation of magnitude of stage I	−0.4%
Nonlinearity of slope and variation in bottoming voltage in stage II	+0.1%
Variation of duration of stage III	−0.8%
Control voltage potentiometer loading	+1.0%

ing oscillator. Stage IV ends when the grid rises to the voltage on the cathode of T_1; this diode conducts, catching the grid.

In stage V, the plate voltage rises till it is caught by T_3, and the circuit is ready for triggering again. The speed with which the plate can return to its initial value so that the circuit can be triggered again is determined by the rate at which grid-plate coupling capacitor C_3 and the strays from plate to ground can be charged through the load resistance.

In this phantastron, then, it is possible to obtain an output delayed in time from the initiating trigger by 20 to 75 microseconds, depending on the setting of the 50,000-ohm linear potentiometer. This delay is closely a linear function of the potentiometer setting.

Pentagrid Phantastron

Chance and his associates at the MIT Radiation Laboratory adapted the original pentode phantastron (developed by the Telecommunications Research Establishment, Gt. Malvern, Worcs., England) to the American type 6SA7 pentagrid converter.[3] In this pentagrid circuit, shown in Fig. 3, grids 2 and 4 (tied internally) are used as the screen grid, grid 3 is used as the grid controlling plate current (the suppressor grid of Fig. 2), and grid 5 is used as a normal suppressor grid (tied to cathode).

One of the advantages of the 6SA7 is that the $e_{g3}i_p$ characteristic exhibits a very sharp cutoff. During stage IV, then, when the suppressor voltage drop begins to cut off the plate current, the rate of cutoff (and therefore the rate of rise of plate voltage) is more rapid than in the normal pentode. This plate voltage rise, reflected to the grid, causes the cathode voltage to rise steeply, producing a sharply defined output pulse.

The addition of the cathode follower allows the plate to return to its initial value much more rapidly than in the simple phantastron. In the latter circuit, the grid-plate coupling capacitor and strays must charge through the high load resistance. With the cathode follower circuit of Fig. 3, the cathode follower charges C_3 and only the strays charge through R_L, so the rate of rise of plate voltage is extremely rapid. The wave forms in this phantastron are shown in Fig. 4.

Maximum Duty Cycle

The duty cycle is defined as the ratio of delay time to the time between successive triggers. Since the recovery is an exponential charging toward B+, the maximum control voltage is normally limited to less than 90 percent of the supply voltage; otherwise, the recovery time would be undesirably long. When this limitation exists in the simple circuit of Fig. 2, the recovery time at maximum delay approximately equals the delay time (50 percent duty cycle).

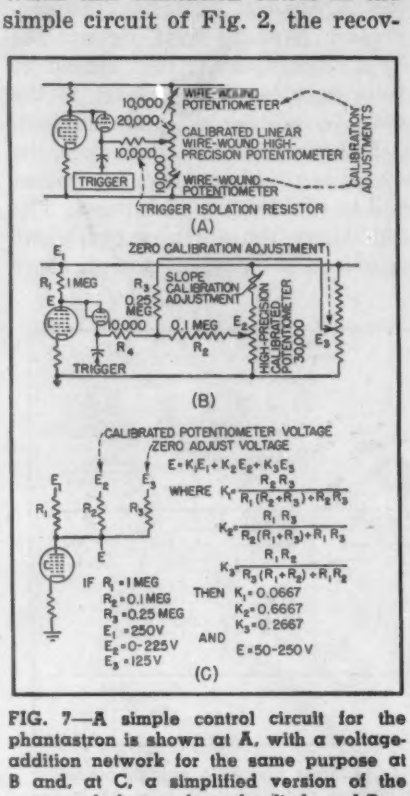


FIG. 7—A simple control circuit for the phantastron is shown at A, with a voltage-addition network for the same purpose at B and, at C, a simplified version of the network that neglects the diode and R_4

If a cathode follower is used to charge C_3 during recovery (stage V), the duty cycle is limited only by the time required to charge the stray capacitance between the phantastron plate and ground through the large plate resistor as mentioned above.

Maximum Delay

If the phantastron is pressed beyond the maximum permissible duty cycle (stage V incomplete), the delay is no longer a linear function of the control voltage; if pressed far enough, erratic triggering will result. In cases where 100 percent duty cycle is required, two phantastron delays may be employed in series, or a fixed video delay line may be inserted in series with the phantastron trigger.

The maximum delay may be calculated from the approximate formula $T_{max} = R_3C_3(V_{max} - V_o)/E_{bb}$, where V_{max} is the maximum value of control voltage and V_o is the minimum control voltage which results in delay (40 to 60 volts).

Minimum Delay

When the phantastron is triggered by a positive trigger applied to grid 3, the delay may be reduced smoothly to zero by continuously lowering the control voltage. When a negative trigger is used, the minimum delay is a function of the trigger width and amplitude. In either case, however, linearity of the delay with control voltage begins to suffer when the value of delay becomes less than 2 percent of the maximum delay.

Linearity

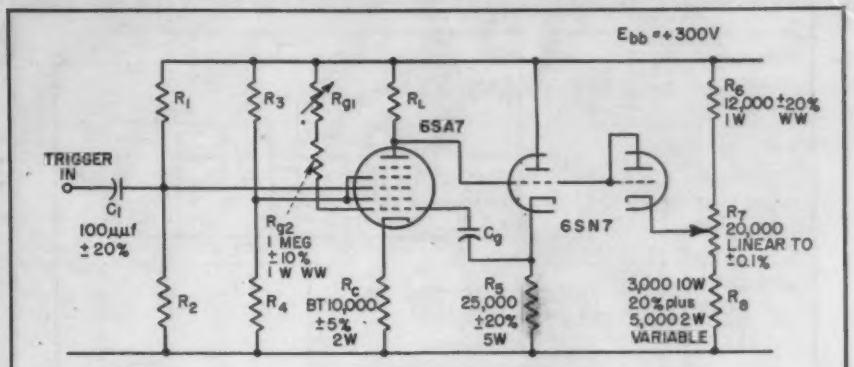
A linearity error of ±0.1 percent of T_{max}, when T_{max} is greater than 200 microseconds, is obtainable under laboratory conditions, while a linearity error of 0.25 percent has been achieved in mass production. Linearity error is defined as the maximum difference between the actual delay and the delay value determined by straight-line interpolation between two calibration points located near the maximum and minimum delays respectively. The linearity obtainable becomes poorer

as the value of T_{max} decreases. Thus, for a phantastron operating between 3 and 50 microseconds, 0.5 percent linearity error is the smallest easily attainable.

In order to obtain the above linearities, careful selection of circuit values is necessary. This is particularly true since there are unavoidable nonlinearities in the various phases of operation whose effects can be eliminated only by carefully balancing as closely as possible one against the other, and deriving the necessary additional compensation from the loading of the control voltage potentiometer by the phantastron plate resistor. Table I summarizes these sources of nonlinearity and roughly indicates their magnitude and direction for the case of a 300-microsecond phantastron.

Particularly important in obtaining good linearity are the values of quiescent screen voltage (on grids 2 and 4), the second control grid voltage (on grid 3), and the values of the plate and cathode resistors. Table II gives recommended component values for four different values of maximum delay.[3] Obviously, if the linearity of the phantastron is to be utilized, a calibrated potentiometer or other type of control circuit of very high accuracy must be employed to convert voltage into a dial reading or a mechanical computer input.

Table II—Recommended Values of Phantastron Circuit Components



Parameter	Resistor Type for Temp Comp	500-μsec Phantastron	2,500-μsec Phantastron	10,000-μsec Phantastron	50,000-μsec Phantastron	Tolerance
R_1	BT	68,000 (2w)	68,000 (2w)	50,000 (2w)	50,000 (2w)	5%
R_2	WW	5,600 (1w)	6,200 (1w)	5,000 (1w)	5,000 (1w)	5%
R_3	WW	20,000 (10w)	20,000 (10w)	15,000 (10w)	15,000 (10w)	5%
R_4	BT 50% / Erie 50%	8,200 (1w)	6,200 (1w)	5,600 (1w)	5,600 (1w)	5%
R_L	BT	1 meg (1w)	2 meg (1w)	5 meg (½w)	5 meg (½w)	20%
R_{g1}	WW	0.1 meg (2w)	0.1 meg (2w)	0.1 meg (2w)	0.1 meg (2w)	20%
C_g	———	90 μμf	475 μμf	2,000 μμf	5,000 μμf	10%
	Temp coeff	N150	N150	N270	N270	

Temperature Compensation

To retain linearity and calibration at widely different ambient temperatures, special care must be exercised in the choice of resistor and capacitor types used. Types indicated in Table II and in the circuit diagrams of Fig. 5 and 6 were chosen so that the effects produced by their variation with temperature would balance as nearly as possible. Both positive and negative coefficient resistors and capacitors are specified.

Unfortunately, it has been found difficult to reproduce results of temperature cycling tests when temperatures are carried to the extremes required by Service specifications. Apparently, a hysteresis type of effect or permanent change in temperature coefficient of some of the standard carbon resistors occurs which upsets the compensation after several temperature excursions. Also, variation in the temperature coefficients of the carbon resistors from lot to lot is common. The best results achieved in practice showed a variation of roughly 0.5 percent in the phantastron calibration over the temperature range of −50C to +70C, with most of the variation at the extremes of temperature.

If it is desired to reduce the temperature effect over moderate ranges of ambient temperature, the types indicated in the table should be satisfactory. If a more rigid compensation is desired, it is recommended that an investigation be made for that purpose. This is particularly true since the local temperature surrounding each component is the significant factor in determining its behavior, and this depends greatly on chassis layout.

Supply Voltage and Tube Variations

Variation of the plate supply voltage over a ±10 percent range produces a change in the delay value of roughly ±0.1 percent of maximum delay. Variation of heater voltage over a ±10 percent range produces roughly a ±0.1 percent change, but in the opposite direction. For this reason an unregulated supply is normally used with the phantastron, since heater and plate-voltage changes very nearly compensate for one another when the line voltage is altered. The control voltage must be derived from voltage-divider type networks operating from the same supply as is used for the phantastron circuit itself, so that it drifts exactly in proportion to the plate and screen voltages.

Linearity is not adversely affected by change of tubes, but calibration may change several percent. Calibration adjustments are provided in the control circuit for this reason.

Trigger Requirements

A trigger of at least 30 volts amplitude is recommended. A positive trigger may be supplied to grid 3 or a negative trigger supplied to grid, plate, or cathode. Injecting the trigger through the control voltage diode has the advantage of removing the effect of the triggering circuit once the operation has begun. The 10,000-ohm resistor shown in series with the diode (Fig. 5) is provided in order to isolate the trigger from the stray capacitance which exists if the control voltage lead travels any appreciable distance to the control circuit, which may often be in a remote location. A duration of at least 2 microseconds is recommended for the posi-

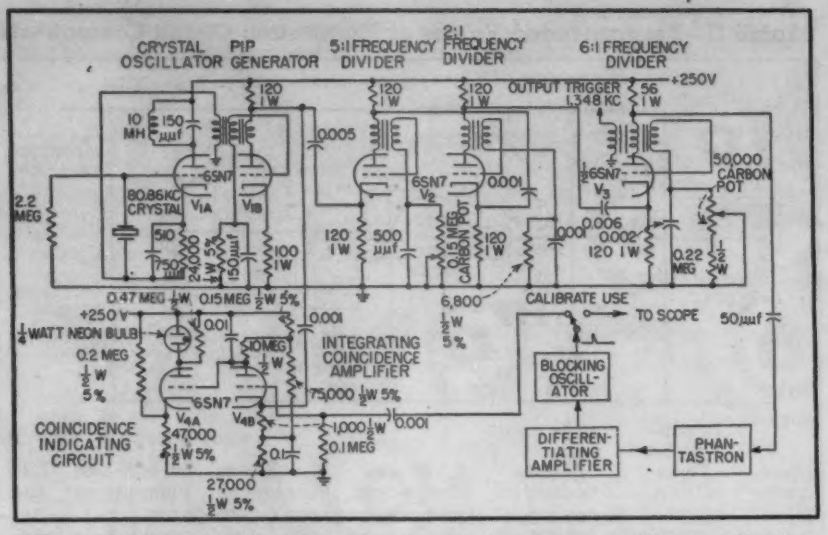


FIG. 8—Crystal-controlled trigger source and neon lamp coincidence calibrating circuit for use in conjunction with a phantastron delay. All pulse transformers are the same type as in the circuit of Fig. 5

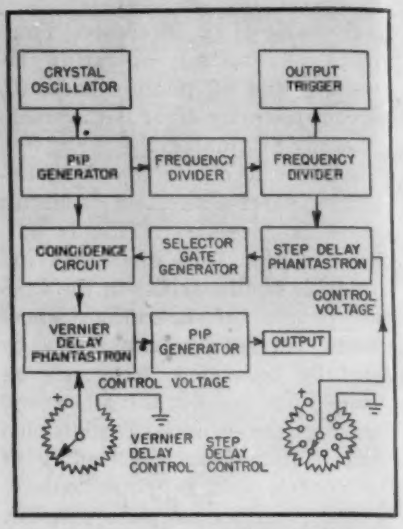


FIG. 9—In two-scale delay circuit, step-delay phantastron produces uniformly spaced pips to trip vernier phantastron

tive trigger to ensure reliable operation. The negative trigger may be somewhat shorter.

Control Circuits

As has been mentioned previously, the control circuit is a network designed to produce a voltage varying from roughly 50 volts, where plate bottoming and hence zero delay occur, to a value somewhat less than the supply voltage. This voltage may be derived from a calibrated potentiometer used in a voltage divider circuit, as in Fig. 7A. The rheostats in series with each end of the potentiometer are varied until the voltages at the ends, or at two calibration points near the ends of the potentiometer, are correct. Since the rheostats interact on each other, several successive settings of each rheostat must be made before a solution is converged upon.

In certain applications it is desired to produce the control voltage from an electronic computer whose output may be the sum or product of several variable quantities. Here it is often inconvenient or impossible to supply the 50 volts of zero-delay voltage in the simple way described above.

Figure 7B shows a resistance mixing or linear voltage addition network which allows the addition of any number of variable or fixed voltages to produce the desired control voltage. The plate resistor of the phantastron is considered as part of the network and is actually used to contribute most of the zero voltage by the current it draws from the network.

Figure 7C is an equivalent circuit of the adding network. The diode resistance and the 10,000-ohm trigger isolation resistor are ignored since they have no effect on linearity and have only a second-order effect on the calibration, which may be ignored initially.

As seen from the equations in Fig. 7C, the resultant voltage on the phantastron plate is composed of definite fractions of the calibrated potentiometer voltage E_2, the supply voltage E_1, and the zero calibration potentiometer voltage E_3. When the calibrated potentiometer arm is grounded, the zero-calibration potentiometer contribution plus the supply voltage contribution should produce the voltage required for zero delay. A slope calibration adjustment is also provided in series with the top end of the calibrated potentiometer. These two adjustments are virtually independent of one another.

If desired, additional branches may be supplied to add additional voltages, and the slope calibration rheostat may be used as a multiplier control to multiply the calibrated potentiometer reading by any desired factor. If the latter is done, the slope calibration rheostat should be replaced by a low-impedance potentiometer connected across the supply voltage, in order not to change the impedance at the slider of the calibrated potentiometer.

The phantastron exhibits sizable calibration drifts with ageing of tubes and should be calibrated against a frequency standard or other timing standard at intervals of 20 to 50 hours of operation. Figure 8 shows a crystal-controlled timing circuit and a calibration indicator which may be built into the phantastron chassis for this purpose. It consists essentially of a crystal-controlled oscillator synchronizing a frequency-divider chain which produces a trigger at a submultiple of the oscillator frequency. This trigger is used to trigger the phantastron and any external equipment it is desired to synchronize with it.

The oscillator has a frequency of 80.86 kc, so that negative synchronized pips 12.37 microseconds apart (exactly one nautical mile of radar range) are produced at the output of V_{1B}. These pips are fed into the cathode of V_{4B}, which is normally biased well beyond cutoff, and are of sufficient amplitude so as to bring the grid almost up to cutoff. In this condition, a positive pulse applied on the grid will cause conduction of plate current and will appear amplified at the plate. A positive pulse appearing at any other time will not appear at the plate unless it is of very large amplitude.

A large time constant composed of an 0.01-µf capacitor and a 10-megohm plate resistor is used in the plate circuit so as to integrate the amplified pulses into a steady d-c voltage. The voltage is directly cou-

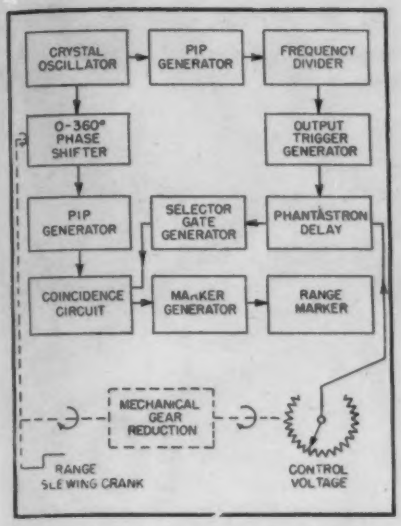


FIG. 10—Block diagram of precision phase-shift delay circuit using a phantastron as an ambiguity resolver

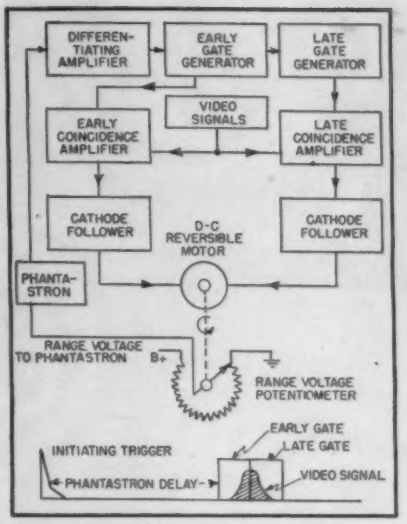


FIG. 11—Block diagram and timing diagram of a phantastron delay for automatic tracking of moving radar signals

pled to the grid of V_{4A}, which is essentially a cathode follower normally biased so as to draw sufficient current to light the 0.25-watt neon bulb in its plate circuit.

The delayed pulse controlled by the phantastron circuit is fed into the grid of V_{4B}. As the delay is adjusted so as to coincide with the first one-mile interval of the pip generator, the phantastron delayed pulse comes into coincidence with the first one-mile pip and a voltage is built up across the plate load. This lowers the bias on V_{4A} and causes the neon lamp to dim. The bias on V_{4A} is set so that the lamp does not completely extinguish, since the voltage required to restart the glow discharge is appreciably higher than its extinction voltage, and dead space or electronic backlash would be introduced.

By selecting two crystal-controlled pips—one near each end of the delay range to be covered—the zero and slope may be set by setting the calibrated potentiometer to read the proper value and adjusting the calibration adjustments until the neon lamp dims. The one-mile pip is used rather than the zero pip since the phantastron is nonlinear in the region of zero delay. The proper pip may be chosen by counting the number of times the light blinks as the calibrated potentiometer is turned through its range.

Cascade Delay

Where a long delay of very high precision is required, the 0.1-per-cent accuracy of the phantastron may be improved by using two or more of them in a cascade delay (Fig. 9). The first phantastron is controlled by a step-type potentiometer calibrated so as to produce equal increments of delay as it is advanced from one position to the next. The output of this phantastron fires a narrow selector gate which is injected into the cathode of a coincidence amplifier. Crystal-controlled pips are fed into the grid, and the desired pip appears amplified at the plate. The position of this pip is independent of the calibration errors of the phantastron (so long as these are not larger than half the width of the selector gate), and is accurate within the precision of the crystal oscillator. This accurately delayed pip is then used as a trigger for the second or vernier phantastron, which covers the time interval between pips. In this way a long time interval can be measured with the precision normally achieved in measuring a much shorter time interval. One of the drawbacks encountered in this method is the nonlinearity of the vernier phantastron at the lower end of its range. This can be overcome by overlapping the vernier phantastron into the second pip interval.

A more convenient type of two-scale delay employs a precision RC phase-shift network to shift the phase of the crystal oscillator continuously through 360-degree cycles (Fig. 10). This produces a set of synchronized pips which appear to travel continuously in time as the capacitor is rotated continuously through many cycles of phase shift. By using a phantastron and selector gate to follow a particular pip and exclude all others, a continuously variable delay of high precision is obtained. In practice, the phase-shift capacitor is geared mechanically through a speed reduction box to the phantastron control voltage potentiometer so as to provide tracking.

Automatic Tracking

Where it is desired to measure a changing time interval continuously, such as in an antiaircraft radar, the delayed pip may be made to follow the target pulse automatically. A simple version of such a system is shown in Fig. 11. Two gates adjacent in time, called the early and late gates respectively, are positioned by the phantastron. Through an electronic or electromechanical servo loop the phantastron voltage is continuously adjusted so as to keep the target pulse exactly split between the early and late gate.

The area of the pulse falling in the early gate is measured by a coincidence amplifier gated by the early gate, while the area falling in the late gate is measured by a coincidence amplifier gated by the late gate. The two coincidence amplifier d-c voltages may then be used to operate a small d-c motor which through suitable gearing turns the range voltage potentiometer (and phase-shift capacitor in the case of a two-scale delay) so as to correct the position of the gates.

Adequate damping must be employed to prevent oscillation or hunting of the servo system. Rate-measuring circuits may be included in conjunction with memory circuits to maintain a continuous rate of change of delay in absence of signal or when the scanning radar beam is off the target.

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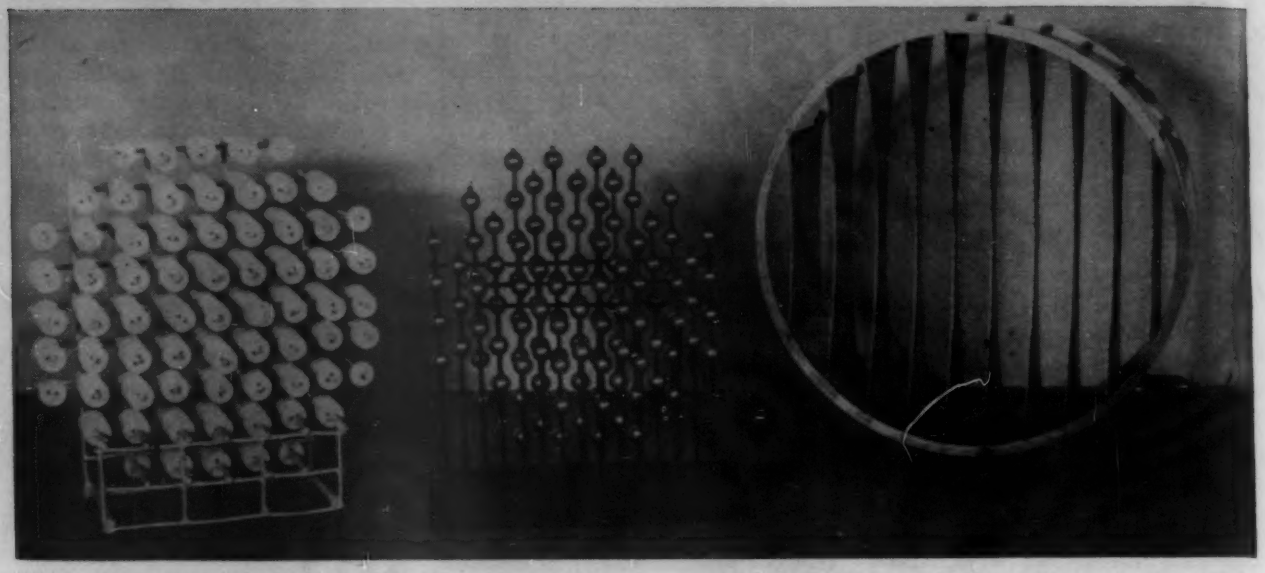

FIG. 1—Dielectric action can be reproduced at microwaves by arrangements of metallic discs (left) or spheres (center). Lenses using metallic dielectric are useful over greater bandwidths than the waveguide type lens (right)

Broadband Lens Antenna for Microwaves

Metal pieces distributed like atoms in large-scale replicas of crystal lattices produce focusing action. Lenses constructed of metallic dielectric made in this manner operate over the very great bandwidths that are desirable for efficient microwave radio relays

BEAMING of microwaves can be accomplished by metallic-dielectric lenses. In contrast to waveguide-type metallic lenses, which transmit waves at higher phase velocities than does air, metallic-dielectric lenses focus by transmitting the waves at lower phase velocities.

Because their refractive power depends on composition, and not on wavelength as in waveguide lenses, dielectric lenses can focus a very wide band of frequencies. Thus they constitute a desirable component for multichannel radio relays, comparable in bandwidth-handling ability to the traveling-wave tube.

To aid in initial design a metallic-dielectric lens was formed by scaling up a crystal lattice responsible for the focusing of light waves. Figure 1 shows two types of such lenses in which small pieces of metal grouped in close array produce the same action on microwaves as atoms in crystal lattices produce on light waves. A waveguide-type lens is also pictured.

Metallic Dielectrics

Metallic lenses of the waveguide-type are now being used in the New York-to-Boston microwave-relay link. The refractive power of these lenses, employing thin metallic plates, depends on the length of the radio waves passing through them. As a consequence, waves having different wavelengths are focused at different points. The bandwidth over which such lenses operate satisfactorily is limited to about 20 percent of the center frequency for most microwave applications.

It is known that lenses made of glass or polystyrene focus microwaves just as they do light waves, and that they operate satisfactorily over a very wide range of wavelengths. However, for many applications such lenses would have to be 10 feet or more in diameter and would weigh several tons. It seemed logical to believe, however, that if the atomic lattice structure, which physicists think constitutes the molecules of a crystalline material, can focus light waves, a scaled-up version or model of this lattice structure would also focus electromagnetic waves of equally scaled-up wavelength.

The advantage to be gained by this procedure is that the individual elements of the scaled-up lattice can be made of metal. Furthermore, because radio waves induce currents only on the surface of the lattice elements if these elements are spheres they can be made hollow,

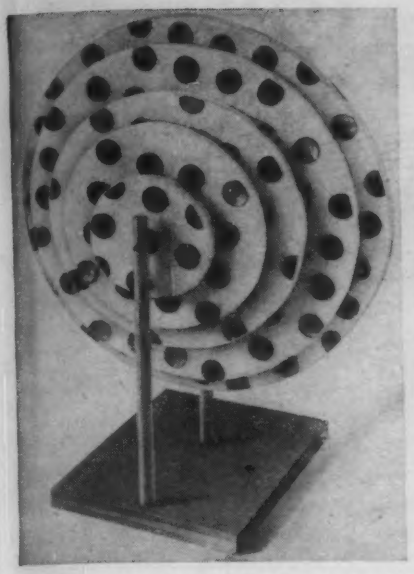

FIG. 2—Broad band microwave lens model is large-scale replica of crystal lattice, made by pasting metallic discs on polystyrene foam

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or can even be thin metal-foil disks, as in Fig. 2. By this means it is theoretically possible to build a lens having only one-thousandth the weight of an equal-size glass lens. Actually, the new lenses are made heavier than this to give them the required strength, but they still weigh less than glass lenses.

Properties of Lenses

Artificial metallic dielectrics reproduce, on a much larger scale, the electronic processes occurring in their true dielectric counterparts. The free electrons in the metallic elements of the array flow back and forth under the action of the alternating radio field and cause the elements to become oscillating dipoles similar to the oscillating dipoles of the dielectric. The array thus exhibits polarization, a property of dielectrics related to their refractive or focusing power. Since the array of conducting elements refracts or bends radio waves, it can be formed into a lens for focusing microwaves.

For broad band operation, the only requirement is that element spacing and size be small relative to the minimum wavelength to be employed. When the spacing of the lattice becomes larger than the wavelength the waves become diffracted and, instead of producing the desired single sharp beam, a diffraction pattern results. The energy is then scattered in many directions, as in the case of x-ray diffraction patterns where the wavelength is short compared to the crystal-lattice spacing.

If the elements are not small relative to the wavelength, they may become resonant and the refractive power of the array will change with wavelength. The material then exhibits dispersion, and although this is objectionable in a lens, the property might be useful. For example, a prism built of such a dispersive refractive medium will split the frequency bands of a multichannel radio wave just as a glass prism splits white light into the colors of the visible spectrum. Separate receiving antennas could then be placed in the proper position relative to the prism to pick up the individual channels of the radio wave as in a spectrometer.

Dielectric vs Other Types

Both the new lens and the earlier waveguide lens are metallic lenses in that their refractive power is due solely to the metallic members which constitute them. The advantage of the new lens is its property of being effective at many wavelengths. All of the advantages of the earlier waveguide lens such as tolerance, beam-forming qualities and shielding protection are retained in the new lattice lenses. As in glass or dielectric lenses, the waves are slowed down or delayed; they may therefore be called metallic delay lenses. Figure 3 shows the difference in action to the two types of lenses.

Regarding tolerance, the advantages of a lens-type microwave antenna over a reflector type are considerable. They result chiefly from the warping which is permitted in a lens but not in a reflector. The gain of an antenna is reduced when the emerging phase fronts are not absolutely flat. If the two halves of a paraboloid are displaced from the mean surface by only 1/20 of a wavelength (a fraction of an inch at microwavelengths), the gain is down 1.7 db. Figure 4 shows that a lens, on the other hand, can be twisted (or displaced) from its correct position without serious effect. Thus, a warping of the final lens can be tolerated which would completely ruin the performance of a reflector. In addition, a horn can be readily used with a lens to shield

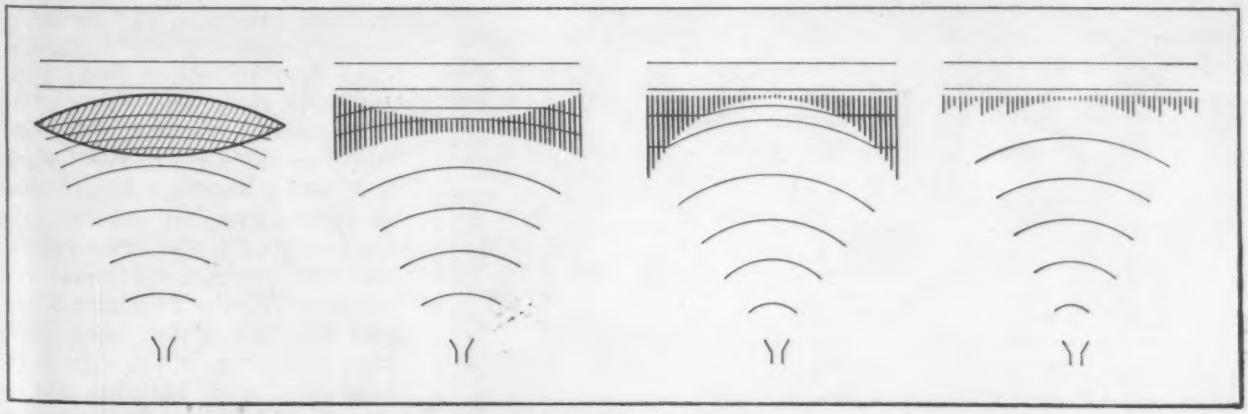

FIG. 3—Metallic-dielectric lens (left) delays waves in proportion to its dielectric constant to produce focusing. Waveguide lenses, three forms of which are also shown, advance waves in proportion to thickness to produce focusing

the system from side radiation.

The fundamental principles involved in the conception of the metallic delay lens are based on the polarization engendered by the presence of the metallic elements. The dipole strength or effectiveness of the element is expressible by means of its polarizability (which can be calculated). The effective dielectric constant of the array is then given as the sum of the free-space dielectric constant plus the product of the number of elements per unit volume times the polarizability. This is expressible by the equation $\epsilon = \epsilon_0 + N\alpha$. The effective dielectric constant is thus seen to be increased either by greater density of elements or by increasing the polarizability α of the individual element. Since the polarizability of spheres, discs or strips can easily be calculated theoretically the effective dielectric constant of an array of such elements can also be determined to permit the design of delay lenses.

Since lenses of this type will effect an equal amount of wave delay at all wavelengths which are long compared to the size and spacing of the elements, they can be designed to operate over any desired bandwidth. For large operating bandwidths, the stepping process used in waveguide lenses (Fig. 1), is to be avoided since a step design is correct only at one particular wavelength. Unstepped lenses are thicker, but the diffraction at the steps is eliminated and higher gain and superior pattern are achieved.

Antenna for Radio Relay

Although the metallic dielectric can be designed in various forms, such as the sphere array and disc array, one form that is simple to construct is that employing metal strips as the polarized elements. Such construction allows the use of only one type of wave polarization (the disc and sphere types focus any type of polarization; vertical, horizontal, circular, elliptical). However, by using polystyrene-foam slabs having slots cut in them, the assembly and support of the strip array is made quite simple, as shown in Fig. 5. Polystyrene foam is light (1.5 lb. per cubic ft.), has negligible effect on the waves ($\epsilon = 1.02$), and yet provides a strong, rigid support for the strips which may then be made only a few thousandths of an inch thick.

Knowing the index of refraction of the artificial dielectric, the shape or profile of the lens required to give a desired focal length can be calculated from optical-ray theories. The proper profile is marked on each foam slab, and the slabs are stacked on top of one another to form the complete lens.

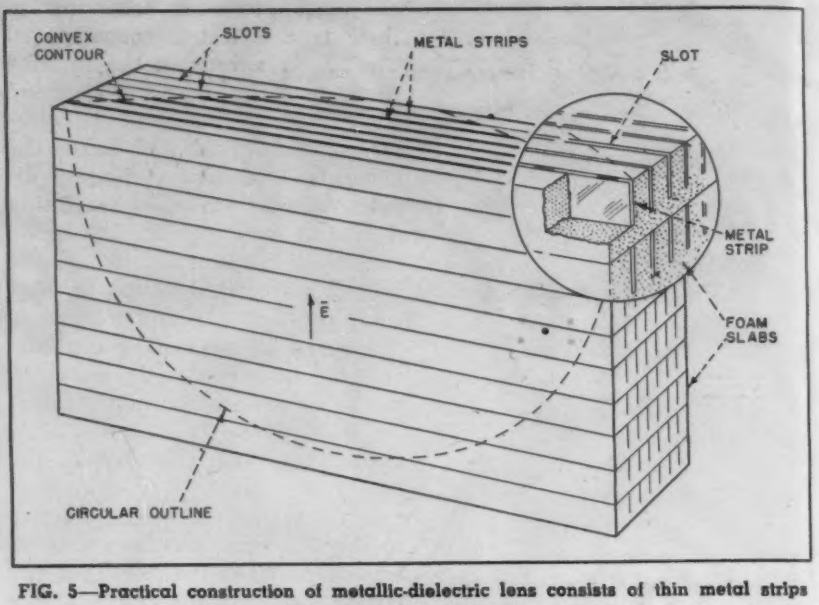

FIG. 5—Practical construction of metallic-dielectric lens consists of thin metal strips instead of spheres or discs

The complete antenna with horn shield has an exterior appearance much like the waveguide lenses now in service. The lens is protected from the weather by a plastic cover. One antenna with shield, planned for the New York to Chicago relay, exhibited an effective area (efficiency) of 60 percent of its actual area over a 500-megacycle band of frequencies at an operating frequency of 4,000 megacycles. In contrast to this, ten-foot square waveguide lenses have only a 50 percent effective area at midband and fall off 1.5 db in gain at the edges of the band. The impedance match of the new lens was under 0.5 db standing-wave ratio and the directional pattern in the horizontal plane had its minor lobes suppressed 35 db or better.

The gains afforded can be illustrated by an example. For a relay link, two six-foot shielded lenses, one transmitting at one end and one receiving at the other end of the path, increase the power received by 73 db or 20 million times over the case of two open (isotropic) radiators at the same path separation. Each antenna has a gain of 36.5 db over an isotropic radiator.

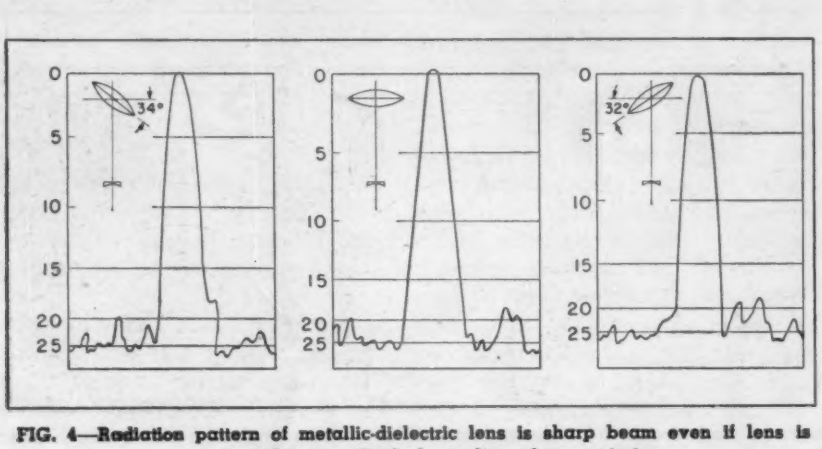

FIG. 4—Radiation pattern of metallic-dielectric lens is sharp beam even if lens is not oriented perpendicularly to line of transmission

Rugged Electron Tubes

Improvements made in construction of electron tubes prevent mechanical failures caused by extremes of shock and vibration and increase useful life under such conditions. Methods of testing and details of specific types are included

By IRWIN L. CHERRICK

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RUGGED electron tube development was the outgrowth of military demands early in the war, when it was found that existing tubes were inadequate to satisfy the requirements of the severe conditions of military usage.

Requests by the Bureau of Ordnance and the Bureau of Aeronautics in 1943 to the Bureau of Ships established an intensive development program whose objective was to make improvements in electron tubes to prevent mechanical failures caused by extreme gunfire, shock and vibration, and to increase useful electrical life.

The Naval Research Laboratory, with the cooperation of the Bureau of Ships, prepared basic specifications whose essence follows:

The existing electrical requirements and operational limits listed in Joint Army and Navy Electron Tube Specifications are to be met, and in addition the tube structures are to withstand vibration over a range of frequencies tentatively set between 0 to 60 cycles per second at an amplitude of 0.04 or 0.10 inch. No structure is to exhibit pronounced mechanical resonance, within the frequency range tentatively set between 0 and 100 cycles per second. Structures are to withstand vibration for sustained periods, tentatively set at 96 hours, and withstand high impact shock similar to that encountered in service.

In addition, low factors of microphonic audio-frequency and radio-frequency noise are listed for development.

Types of Shock

Shocks occurring aboard ships and military vehicles arise from the firing of guns, near hits, depth charges, mines and obstructions found in travel. Other shocks sufficient to damage apparatus may result from dropping or rough handling equipment. Accelerations lasting for about a millisecond may easily extend up to magnitudes of 1,000g (g=acceleration due to gravity) at electron tube locations for severe shocks.

Destructive vibrations are another source of damage to military equipment. Shipboard vibrations may be expected to be of an amplitude not more than 0.04 inch and of frequency from 5 to 30 cycles. Priebe of the Squier Signal Laboratories has found that vehicular vibrations may range from 1 to 3 cycles per second at 5g, 10 to 60 cycles per second at 2g, up to 60 to 100 cycles per second at 1g. Aircraft vibrations may be expected in the range from 0 to 10,000 cycles.

High-magnitude accelerations involving very large velocity change present another source of destructive mechanical force to electronic apparatus. Destructive accelerations as high as 15,000 to 50,000g may be experienced when high-ve-

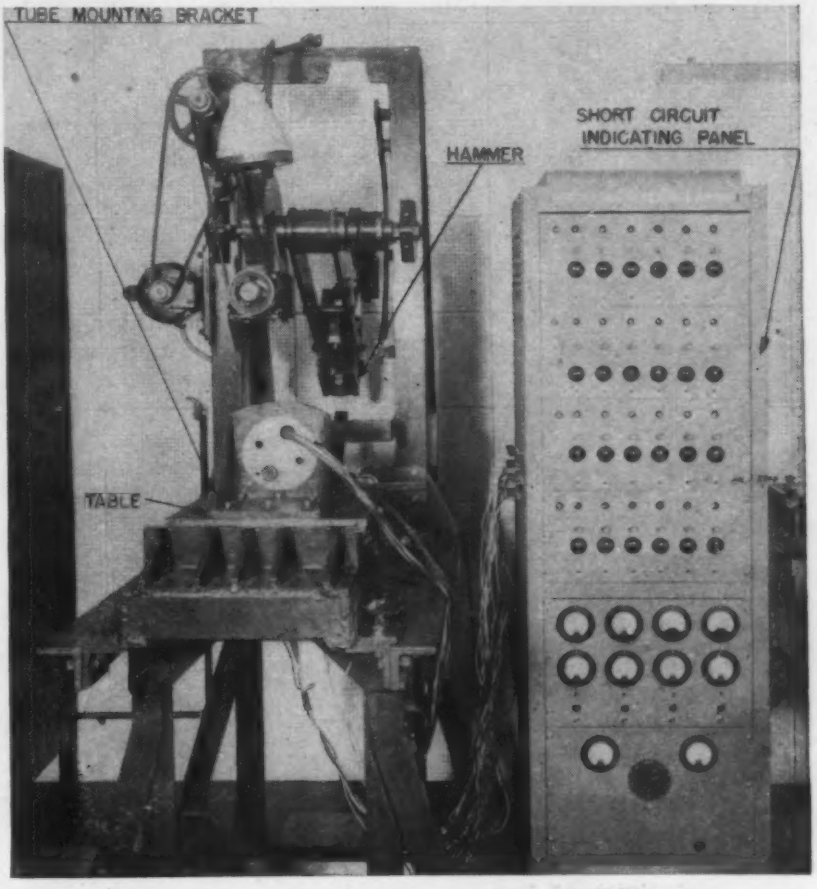

FIG. 1—Flyweight high-impact machine developed at NRL for testing electronic devices

locity projectiles are fired from guns.

Test Equipment

To apply destructive shock for the development of rugged electron tubes, the Naval Research Laboratory designed the Flyweight high-impact machine shown in Fig. 1. In this machine, the shock level is varied by the angle through which a hammer pendulum falls. Shock conditions generated by this equipment are studied by high-speed streak photography and by a quartz crystal type of accelerometer.

The streak photography method of calibration of the shock equipment graphically presents the movement of the hammer and the table and is a recording on a film moving between 3 to 4 feet per second. By this method, a displacement versus time and velocity versus time relationship for the shock equipment may be obtained as shown in Fig. 2.

With the quartz crystal accelerometer, the exact time interval of the initial shock pulse may be obtained. The output of the quartz crystal accelerometer is photographed from a cathode-ray tube by a high-speed camera on a film moving at a speed of about 7 feet per second.

The NRL Flyweight high-impact machine operates by having a steel hammer strike a metal table. The unique features are that repetitive hammer shocks can be given at a certain level and the automatic return of the moving table to which the shock is applied. Samples under examination may be mounted in all planes and rated operating voltages may be applied or other detecting equipment attached.

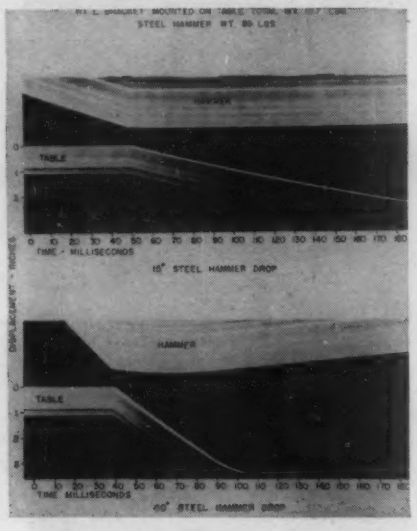

FIG. 2—Streak photographic displacement-time curves obtained on the impact machine with a hammer drop of 15 and 60 degrees

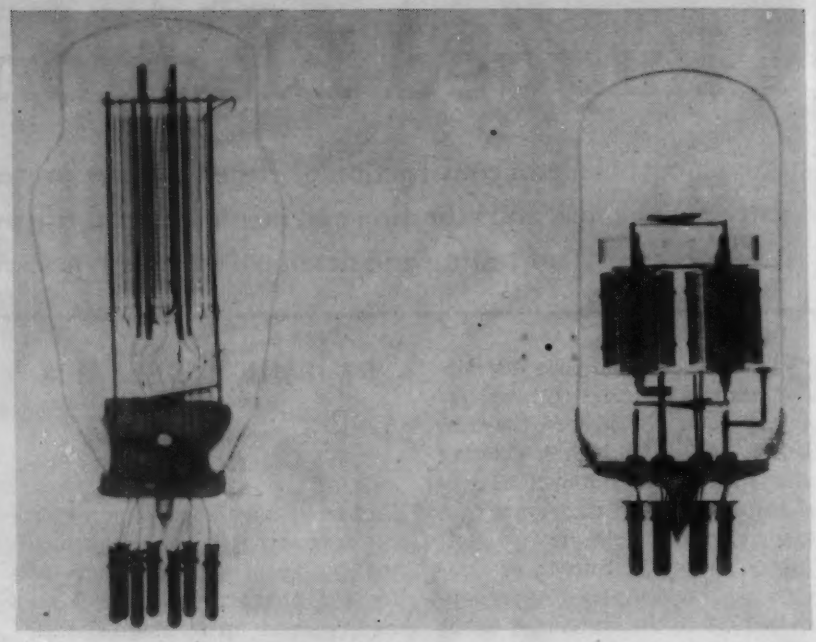

FIG. 3—X-ray view of the nonrugged 6L6GA is shown at left. The double 14A5 construction forming the 6L6WGA appears at right

Other Methods

Continuous vibration provides a method for detecting failures in operation resulting from weakness under torsion, compression, tension or abrasion. The vibration machine is usually designed to carry a large number of specimens and provide examination at specific frequencies of vibration and displacement for sustained periods. Joint Army-Navy Specifications list periods of 96 hours and frequencies of 25 cycles with amplitudes of 0.04 inch. Such failures as abrasion of micas, fatigue of welds and separation of crystalline structures along binding surfaces have been found to exist. Vibration machines have been built to cycle over a range of frequencies at variable amplitudes of vibration.

A device used for mechanical resonance examination at NRL consists of a platform attached to a link-coupled voice coil of an electrodynamic loudspeaker and vibrated at frequencies from 15 to 15,000 cycles per second. Joint Army-Navy Specifications require, in some cases, no pronounced resonance in tube structures to 100 cycles.

Two Tubes in One

Figure 3 is an x-ray photograph of the rugged and nonrugged 6L6GA tube. The rugged tube was developed for the Navy Department with the cooperation of the Naval Research Laboratory, by Sylvania Electric Products Inc.

The original 6L6GA structure used a flare stem and ST14 bulb. Even in normal handling the cathode would bow at times, causing cathode to grid shorts. The rugged version or 6L6WGA was required to be interchangeable electrically with the 6L6GA and fit in the same space. Two 14A5 tubes were mounted side by side in the bulb and connected in parallel internally. This structure is only half as long as the 6L6GA and preliminary electrical checks using two 14A5 lock-in tubes in parallel showed the scheme to be practical.

The bulb was changed from ST14 to straight-sided T12, evidently to make a seal to the wafer header. The stem was changed from flare stem to a modified lock-in stem, a flat wafer with 8 pins running through the glass and arranged on a circle that coincides with the pin circle of the standard octal base. A special large diameter octal base is used, though the greatest outside

diameter of the finished tube is no larger than the largest diameter of the 6L6GA.

A new mica mount accommodates the side-by-side structure of the 14A5's. Each individual structure is unaltered, except that a slightly larger cathode is used to increase the power output to match the 6L6GA. The side rods of the plates are anchored to the mica by welding them to eyelets in the mica. Two of four plate side rods extend through the mica eyelets and weld directly to the stem leads. The mount is anchored to the stem at a third point by a support rod welded to a stem pin and to an eyelet in the mica opposite the other supports, so that an isosceles triangle is formed. The top mica is also anchored by eyelets welded to the plate side rods. Grid stops are provided to anchor the grids in both sections to the top mica.

Mechanical Improvements

Figure 4 is a photograph of the conventional 6AC7 and the developmental rugged 6AC7 produced by Radio Corporation of America.

The wire mount assembly supports of the 6AC7 were replaced by an A-frame support stamped from 0.010-inch thick steel strip. The support was ribbed during stamping for additional strength and combined the grid top shield and mount supports into an integral part. During tube assembly, the supporting legs of the A frame were threaded into engaging slots in the top and bottom micas of the electrode cage and a bottom grid shield was then welded to the legs to lock the mount assembly rigidly together.

The mount support was welded to lugs turned up from the metal plate. The A-frame support removed the strain of vertical shock from the lead wires sealed in glass. No supporting contact was required between the micas and the inner wall of the shell and mica chafing under vibration was reduced.

The folded type of heater was replaced by a helical coil heater. Because the coil heater was free of sharp bends, the heater breakage under shock was reduced appreciably over the folded design.

A metal clip stapled to the top mica and welded to the flat edge of the cathode sleeve was added. The mica clip was made of nichrome to minimize heat conduction from the cathode. This held the cathode securely from lateral motion and eliminated wearing of the cathode hole in the top mica.

Four wire stops were welded to the grid support wires at the extremities of the grid lateral wire winding to prevent vertical travel of the support rods under shock or vibration. This served effectively to prevent crushing of the end turns of the grids against the micas.

Other Types

Chatham Electronics Co. have ruggedized types 2050, 6H6GT and 6AL5 under a Navy contract.

The 6AL5 was ruggedized by an extension of the methods used for the rugged proximity fuze tubes. The acceleration required of these tubes is much less than that required of the fuze tube, but on the other hand, these tubes are much larger than the fuze tubes.

Each part of the tube is carefully assembled to insure that it will carry the intended load. Every weld is able to carry its own load. Several extra welds can not be used to support a single part to allow for a few weak welds (as in low-cost receiving tubes) because the stresses are so great that each one has its own load.

The larger tubes, types 2050 and 6H6GT, were ruggedized by building the element structure in this same manner as the smaller tube. A resilient shock mounting is employed between the glass bulb and the base. The shock mounting is made of molded rubber and is chosen to have a natural period and damping that greatly diminishes the shocks transmitted to the glass.

The rubber mounting withstands all the tests, including torque and water immersion, that are required of regular tubes for military use.

The rubber mounting also simplifies the clamping of the tubes in the socket. To clamp a regular tube sufficiently tight to keep it from slipping out of the socket during shock, enough pressure is applied to the base to frequently crush the glass bulb. In the new tube the pressure is applied to a section of the rubber that does not enclose any glass.

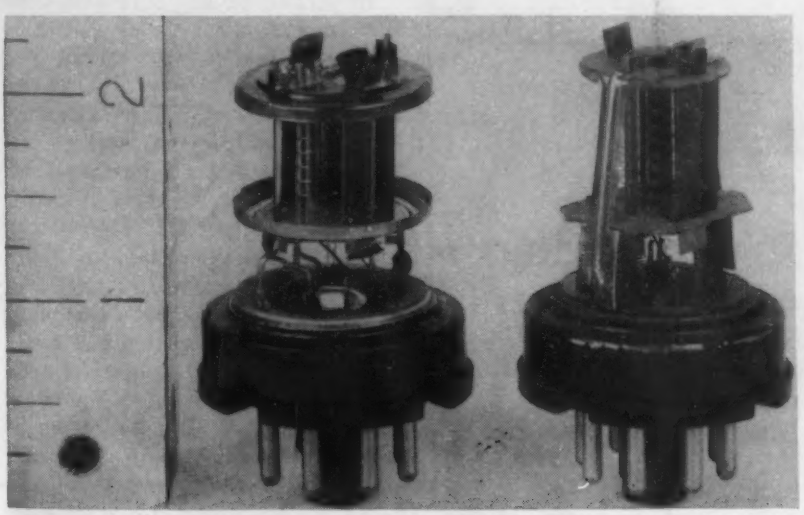

FIG. 4—Construction of the conventional 6AC7 is shown at left and the rugged version at right

Acknowledgment

Appreciation for assistance on work of the Rugged Tube Program is extended to Dr. Irwin Vigness and staff of the Shock and Vibration Section, and J. T. Fetsch and staff of the Vacuum Tube Development Section, Naval Research Laboratory; Walter Greer and staff of Electron Tube Section, Bureau of Ships; E. G. Shower, formerly with Bureau of Ships, now with Bell Telephone Laboratories, and development engineers of the major companies of the electron tube industry who contributed to the tube ruggedization program.

Filter Characteristics for the

Analysis of the cascaded pair of four-terminal networks that form the basis for high- and low-frequency response control in the Scott device. Effect of reactance tubes as variable circuit elements is indicated

IN A RECENT PAPER, H. H. Scott[1] described circuits capable of controlling dynamically the bandwidth of an audio amplifier in accordance with the sound level, so as to maintain an optimum signal-to-noise ratio. Equipment using these circuits is said to realize a life-like response, one devoid of distortion most common in present-day disc systems.

Distortion may be of several different types, such as amplitude, phase, intermodulation products, and background noise. Of these, the most objectionable distortion is that of background noise, one that is difficult to eliminate. It is the purpose of this discussion to describe the theoretical aspects of the filtering circuits and how the dynamic characteristics needed for noise suppression can be obtained.

The dynamic noise suppressor basically consists of two four-terminal networks connected in cascade, each network dynamically controlling the high-frequency and low-frequency response of the audio amplifier, respectively. Each network, in turn, consists of a few lumped parameters, all dissipationless, together with a variable reactance, the value of which depends on the relative signal level. We shall now consider each of the four-terminal networks, investigating them in the manner of conventional filter theory.

For a four-terminal network comprised of two impedances, Z_1 and Z_2, as shown in Fig. 1, the attenuation function can be expressed as the inverse hyperbolic cosine of the square-root of the product of the diagonal elements of the matrix usually referred to as the *ABCD* matrix.[2,3] Functionally, this relation is $\gamma = 8.686 \cosh^{-1} (AD)^{\frac{1}{2}}$ where γ is the reactive attenuation function in decibels, and where A and D are the diagonal elements of the *ABCD* matrix relating the output voltage to the input voltage for the four-terminal network. Now, if we consider what A and D are for Fig. 1A, we find that the attenuation function is

$$\gamma = 8.686 \cosh^{-1}[1 + (Z_1/Z_2)]^{1/2} \text{ decibels} \quad (1)$$

Considering the four-terminal network shown in Fig. 1B, we may write Z_1 and Z_2 as

$$Z_1 = \frac{j\omega L_1}{1 - \omega^2 L_1 C_1}$$

$$Z_2 = j\omega L_2 + (1/j\omega C)$$

If these values are substituted in Eq. 1 the attenuation function becomes

$$\gamma = 8.686 \cosh^{-1} \times \left(1 + \frac{-\omega^2 L_1 C}{(1 - \omega_2 L_1 C_1)(1 - \omega^2 L_2 C)}\right)^{1/2} \text{db} \quad (2)$$

Inspection of Eq. 2 reveals that the attenuation function versus frequency will have, in general, the shape indicated in Fig. 2A. There are two points of infinite attenuation, the frequencies for which we shall designate as f_{c1} and f_{c2}, where the subscripts 1 and 2 refer to the parameter subscripts responsible for the frequencies of infinite attenuation. Furthermore, there is a definite pass band, since this network under consideration is a stop-band filter, and has a critical frequency f_o that designates the edge of the pass band. Finally, we shall define the frequency of minimum attenuation lying between f_{c1} and f_{c2} as f_m. It is merely a matter of algebra and some differential calculus to find these critical frequen-

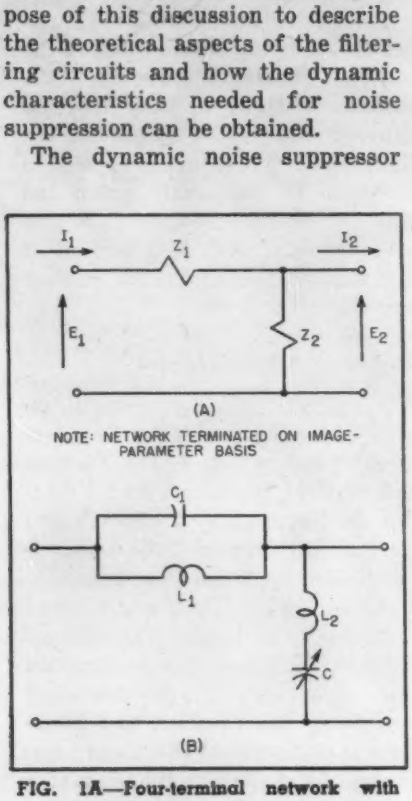

FIG. 1A—Four-terminal network with generalized series and shunt arms

FIG. 1B—A stop-band filter

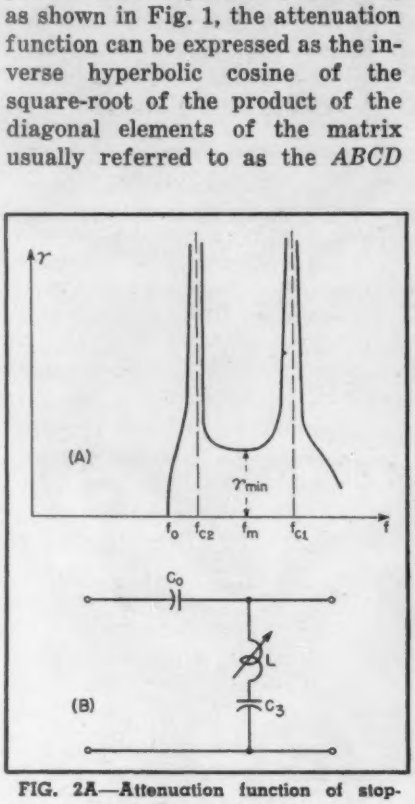

FIG. 2A—Attenuation function of stop-band filter vs frequency

FIG. 2B—High-pass filter

Dynamic Noise Suppressor

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cies in terms of the network parameters, expressed as follows

$$f_{c_1} = (1/2\pi)\,(1/L_1 C_1)^{1/2} \quad (3a)$$

$$f_{c_2} = (1/2\pi)\,(1/L_2 C)^{1/2} \quad (3b)$$

$$f_o \cong (1/2\pi)\,(1/L_1 C)^{1/2} \quad (3c)$$

$$f_m = (1/2\pi)\,(1/L_1 L_2 C_1 C)^{1/4} \quad (3d)$$

Immediately, one notes that of the two frequencies yielding infinite attenuation, one will be constant regardless of the variations of the variable reactance for the capacitor C (Fig. 1B), while the other frequency of infinite attenuation shifts for variations in the reactance of capacitor C. It is this variation that is of paramount importance in the dynamic noise suppressor, for by dynamically altering the value of capacitance C, one may achieve a variable stop-band filter; and, by careful selection of components, one may achieve a characteristic approximating that of the human ear.

For the four-terminal network considered it is possible to find the minimum attenuation in the range of frequencies between f_{c1} and f_{c2}.

$$\gamma_{min} = 8.686 \cosh^{-1} \times \left(1 - \frac{\omega_m^2 L_1 C}{\left(1 - \frac{\omega_m^2}{\omega_{c_1}^2}\right)\left(1 - \frac{\omega_m^2}{\omega_{c_2}^2}\right)}\right)^{1/2} \text{db}$$

where:

$$\omega_m = 2\pi f_m$$
$$\omega_{c_1} = 2\pi f_{c_1}$$
$$\omega_{c_2} = 2\pi f_{c_2}$$

The minimum attenuation will be least when the critical frequencies f_{c1} and f_{c2} are widely spaced, say in a ratio f_{c1}/f_{c2} greater than 10. When this condition obtains, the minimum attenuation in the stop band reduces to approximately

$$\gamma_{min} = 8.686 \cosh^{-1} [1 + (L_1/L_2)]^{1/2} \text{ db} \quad (4)$$

Increasing the ratio L_1/L_2 will raise the minimum attenuation in the stop band, so that the dynamic noise suppressor should be designed with a favorable L_1/L_2 ratio.

Connected in cascade with the four-terminal network above is a high-pass filter of the configuration shown in Fig. 2B. This network is simpler to analyze, and the resulting attenuation function is

$$\gamma' = 8.686 \cosh^{-1} \times \left(1 + \frac{C_3}{2C_o\,(1 - \omega^2 L C_3)}\right)^{1/2} \text{db} \quad (5)$$

where L will now be the variable parameter dependent on signal level. The equation above indicates a resonant attenuation peak which will shift when the L parameter is varied; this peak of infinite attenuation will occur at a frequency f_x, which is

$$f_x = (1/2\pi)(1/LC_3)^{1/2}$$

The characteristic curve for this high-pass filter is shown in Fig 3A. Here, we note that the slope of the attenuation function vs frequency changes gradually, whereas the slope of the characteristic curve for the stop-band filter changed very abruptly. These characteristics resemble those obtained for a constant -k filter and a repeated derivation m- derived filter, respectively.

Combined Networks

The overall response of the combined four-terminal networks is shown in Fig. 3B. If we now permit the L and C parameters to vary linearly as functions of signal level, we note that the bandwidth of the overall circuit changes rapidly in the high-frequency region and slowly in the low-frequency region.

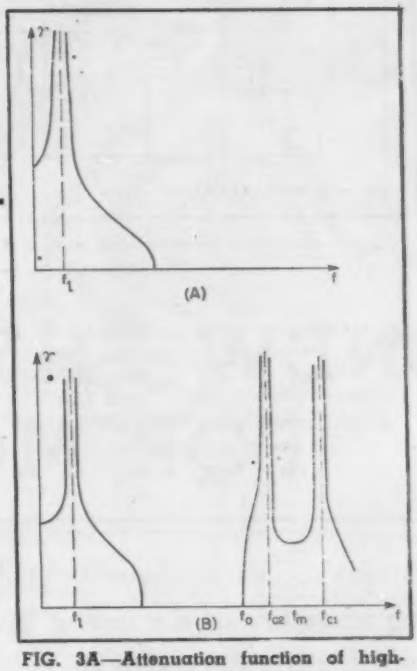

FIG. 3A—Attenuation function of high-pass filter vs frequency

FIG. 3B—Attenuation of overall network as function of frequency

Utilizing the signal level to change the grid bias on reactance tubes in the dynamic noise suppressor, where the reactance tubes replace the variable elements in the networks, and adjusting the circuit to conform to the characteristics of the human ear, we are able to obtain the optimum signal-to-noise ratio that is possible from the given sound source. Sound is used loosely here to correspond to the impressions on disc recordings or the signal at the output of the detector in an amplitude-modulation receiver tuned to an amplitude-modulation station.

We may conclude from the discussion above that there is good theoretical evidence to support H. H. Scott's statements that the dynamic noise suppressor will improve a sound system if it be properly designed.

References

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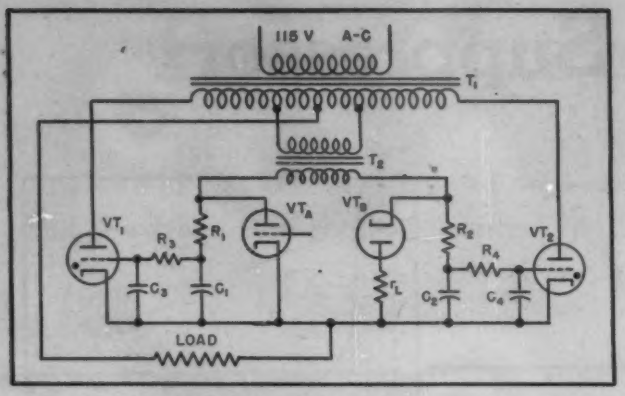

FIG. 1—Capacitor-charging grid control circuit for thyratrons, in simplest form

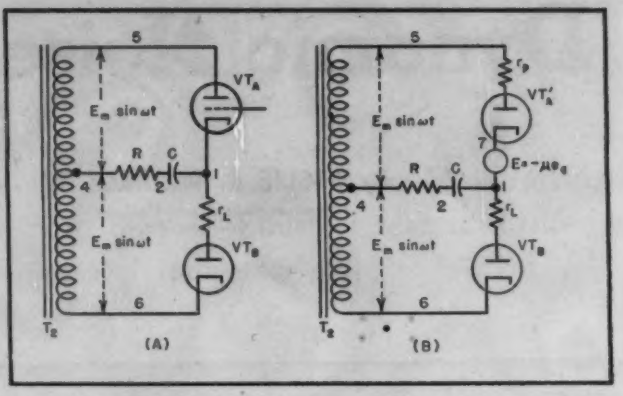

FIG. 2—Basic diode-triode circuit for charging a capacitor, and equivalent two-diode version

NEW THYRATRON CIRCUIT FOR MOTOR CONTROL

Simple capacitor-charging grid control circuit varies firing points of two thyratrons feeding armature of d-c motor, giving smooth potentiometer control of speed over operating range. Auxiliary circuits counteract speed droop with load and limit armature current

ONE METHOD commonly employed for grid control of thyratrons involves applying to the grid a variable d-c potential acting in series with a fixed a-c potential. If the a-c component lags the anode voltage by 90 degrees and the d-c voltage can be varied plus or minus up to the peak value of the a-c component, it is possible to obtain smooth control over the full 180 degrees of positive anode voltage.

The grid control circuit described here falls in this general classification. Its uniqueness lies in the simple means by which the lagging a-c voltage and the variable magnitude and polarity d-c voltage are obtained.

The new grid control circuit is shown in elementary form in Fig. 1. The secondary winding of transformer T_2 applies a small alternating voltage across capacitors C_1 and C_2 which is lagging the anode voltages of thyratrons VT_1 and VT_2 by nearly 90 degrees. The effect of diode VT_A passing current is to put a charge on each of these capacitors with polarity such that each thyratron grid is positive with respect to its cathode.

Control triode VT_A attempts to charge the capacitors with the opposite polarity. The net charge depends upon the relative conductance of the two control-tube circuits, which can be readily varied by varying the grid-to-cathode voltage of VT_A. As the d-c component of voltage across the capacitors is varied from a negative value equal to the peak a-c to a positive value equal to the peak a-c by increasing the negative grid voltage of VT_A, the thyratrons change from full off to full on.

Capacitor Charging Action

A breakdown of the circuit into simpler elements will help to explain how the direct voltage is developed across the capacitors. In Fig. 2A, VT_A is a sharp-cutoff triode in a circuit where the only applied voltage is the alternating voltage from the secondary of T_2. With the grid held constant at some negative value, there is practically no plate current flow until the sinusoidal supply voltage rises to some value (μe_g) which is determined by the grid voltage, after which plate current increases in approximate proportion to the rise in plate voltage above that value. The constant of proportionality is the plate resistance r_p of VT_A.

Triode VT_A in Fig. 2A may be replaced by a perfect diode, a generated voltage $E = \mu e_g$ to oppose current flow until the plate voltage reaches E, and a resistance r_p, as shown in Fig. 2B. This is not a strict equivalent since the plate characteristic curves are not straight lines, particularly near cutoff, but the approximation will be satisfactory for this discussion.

The various voltages existing in the circuit of Fig. 2B when the negative grid voltage is low (E is near zero) are shown graphically in Fig. 3A, all with respect to point 1 in Fig. 2B. Resistor r_L in series with VT_B is made greater than plate resistance r_p. The 60-cycle reactance of C is low compared to R.

In the circuit of Fig. 2B, no direct current can continuously flow through C and R (between points 1 and 4). Therefore, the average currents through r_p and r_L must be equal. This means that the initial excess current flowing through r_p and VT_A' charges the capacitor to

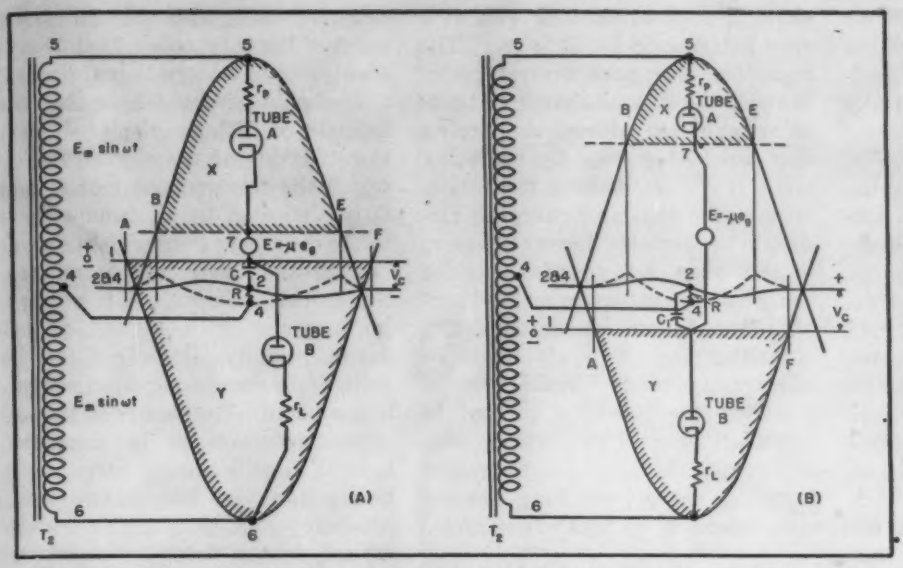

FIG. 3—Conduction diagrams for two-diode circuit of Fig. 2B, illustrating effect of varying voltage E acting in series with upper diode

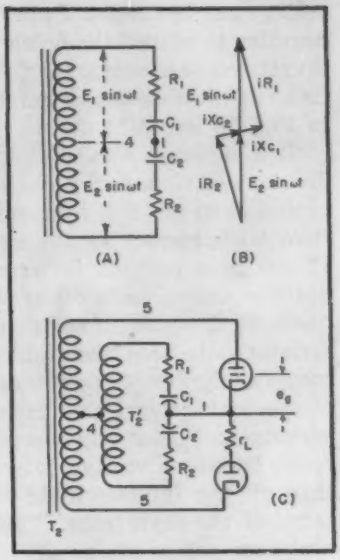

FIG. 4—Circuit variations giving same performance as Fig. 2B

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such a polarity and magnitude that it adds to the lower half of the transformer voltage and subtracts from the upper half, to equalize average currents through r_p and r_L.

As shown in Fig. 3A, the voltage $E_m \sin \omega t - V_c$ acting during conduction period A to F must force the same charge through r_L as the voltage $(E_m \sin \omega t - E) + V_c$ gives through r_p during conduction period B to E, for capacitor C will charge to such a voltage V_c that the areas X and Y have the same ratio as the resistances r_p and r_L.

During the portion of the cycle from F to A there is no current anywhere in the circuit, so the capacitor holds its charge during this time. Since C was chosen such that its 60-cycle reactance was low compared with the resistance R in combination with r_p and r_L, the variation of the voltage V_c across it during the conducting portion of the cycle will be very small.

If the voltage E is increased as in Fig. 3B, the capacitor is charged to a new voltage V_c such that again the average currents through r_p and r_L are made equal, and the ratio of the areas X and Y is made equal to the ratio of r_p and r_L. The charge on the capacitor thus depends upon two things, assuming the transformer voltage to be constant: (1) the ratio of resistance r_p to r_L; (2) the value of E. The ratio of the two resistances is fixed by the choice of tube VT_A and resistor r_L. The capacitor voltage V_c then may be varied by varying the negative grid voltage of VT_A. With r_L greater than r_p, V_c is negative for small values of E (e_g near zero) and goes through zero to positive as E is increased (e_g made more negative).

Equivalent R-C Arrangement

Resistance R and capacitance C can be replaced by a series resistance R_1 and capacitance C_1 in parallel with a like resistance R_2 and capacitance C_2, where $R_1 = R_2 = 2R$ and $C_1 = C_2 = 0.5C$. Now if another center-tapped transformer secondary winding is connected in series with R_1, C_1, C_2, and R_2 as in Fig. 4A, an alternating voltage is applied across the capacitors. The reactance of the capacitors at line frequency is low compared with the resistance of the resistors, hence the alternating voltage across the capacitors will be low compared with the applied voltage, and lagging it by nearly 90 degrees as shown in Fig. 4B.

Since $R_1 = R_2$ and $C_1 = C_2$ no alternating voltage will appear between points 1 and 4. Therefore, the circuit of Fig. 4A can replace R and C in Fig. 2A without affecting the development of the d-c charge on the capacitors, as shown in Fig. 4C. There is now across each capacitor a direct voltage established by the diode and triode, plus an alternating voltage fixed in magnitude and lagging the applied voltage by nearly 90 degrees. With respect to point 1, the alternating voltages on the two capacitors are 180 degrees out of phase. If the voltages of the two transformer secondaries are made equal both in magnitude and phase, the two windings can be made one.

Control of Thyratron Firing

The combined alternating and variable direct voltage across the two capacitors can be used to control the firing of a pair of thyratrons in a half-wave biphase circuit, as shown in Fig. 5. The voltage of the secondary of T_2 is in phase with the voltage of the thyratron anode transformer secondary T_1, making the voltage across C_1 and C_2 lag nearly 90 degrees behind the anode voltages of the thyratrons to which they are connected. By varying the grid voltage of VT_A, the alternating

voltage can be displaced positive or negative to control the firing of the thyratrons over nearly the full positive half-cycle, as shown graphically in Fig. 5B and 5C.

Grid resistors R_2 and R_4 in Fig. 5A are quite necessary during the period when the grid voltage is positive with respect to the cathode. If the grid current is large, the positive charge leaks off of the capacitors. However, if sufficient grid resistance is used the leakage becomes negligible. Capacitors C_3 and C_4 are conventional grid capacitors serving to bypass any steep-wavefront transient voltage introduced through the interelectrode capacitance of the thyratrons. Their capacitance values are small, so that with the grid resistors they introduce only slightly more lag in the a-c component of grid voltage.

Speed of Correction

A change in the charge on the capacitors (a change in the d-c voltage on the thyratron grids) can occur only during half of every cycle of the line voltage. The conditions during the second half of the cycle remain the same as at the end of the first half of the cycle. In other words, a correction of the firing point of the thyratrons can be made only during one half of every cycle.

Referring again to Fig. 2B, if E is made higher than the peak of the alternating voltage $2E_m$ (e_g made very negative), VT_A is biased off completely and the capacitor is charged positive through VT_B at a rate determined by $R + r_L$. The capacitor may take several cycles to reach the desired charge or turn-on voltage even with all the forcing that can be applied. On the other hand, if E is made zero, the resistance in the capacitor-charging circuit is appreciably lower (since r_g is less than r_L) so the negative charge on the capacitor or the turn-off voltage is built up more quickly.

Furthermore, if E is made in effect negative (e_g made slightly positive) the charging current is increased by grid rectification and so forces the buildup of the negative capacitor charge, reaching the required turn-off voltage in one cycle.

Output Voltage Control

To hold the thyratron rectifier output voltage constant, triode VT_A can be connected to compare a portion of the output voltage with a fixed or reference d-c voltage, as in Fig. 6. The cathode of VT_A is connected to the variable arm of R_{15} to permit adjustment of the reference voltage value when a change in speed is desired, and the grid is connected to a fixed portion of the thyratron rectifier output voltage. If the fixed portion of the output voltage becomes greater than the preset reference voltage, the grid voltage of the triode swings positive with respect to the cathode, retarding the firing point of the thyratrons and reducing the output voltage. Conversely, a drop in output voltage causes the triode grid to swing negative and advance the firing point of the thyratrons, so that constant output voltage is maintained.

It should be noted here that the cathode of VT_A is displaced from the cathodes of the thyratrons, to which the common point of C_1 and C_2 is connected, by an amount equal to the difference between the output voltage and the reference voltage. Since this displacement voltage is in series with E and of opposite polarity, its effect can be nullified by increasing E an equivalent amount. The result is that as the output voltage is increased, e_g of VT_A will become more negative. However, the change in e_g necessary to produce a given change in the firing point of the thyratrons is very nearly the same for all values of output voltage.

Complete Practical Circuit

In Fig. 7 is a simple form of thyratron motor control using the new grid control circuit. The voltage across the d-c motor armature, and hence the speed of the motor, is controlled by the potentiometer in the grid circuit of VT_A. The reference d-c voltage for thyratron output voltage control is obtained from the full-wave power supply for the shunt field of the motor (VT_3).

If the lower end of R_{14} were connected to the negative side of the armature, the voltage across the motor armature would be held nearly constant as the motor load is increased. Speed would then droop because of increased armature IR

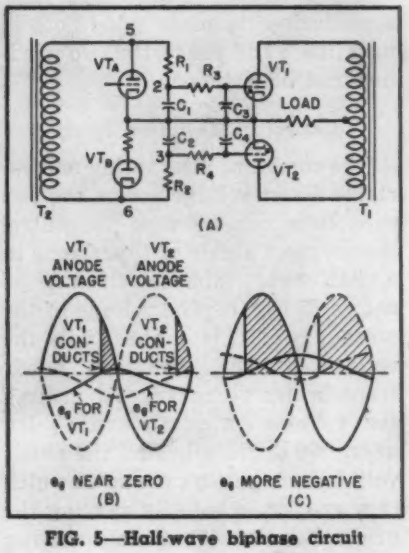

FIG. 5—Half-wave biphase circuit

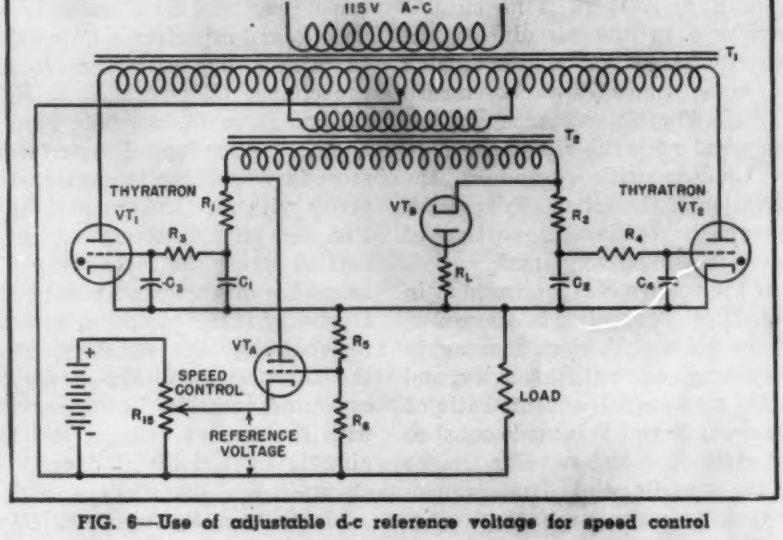

FIG. 6—Use of adjustable d-c reference voltage for speed control

drop as armature current increases to provide the extra torque.

Speed droop with load is generally undesirable, particularly when operating at low speeds. A compensating signal obtained from armature current is therefore inserted in the control circuit. This signal is adjusted with R_{18} to make armature voltage rise by exactly the amount of the increased armature IR drop.

The compensating signal, a voltage proportional to armature current, is obtained from full-wave rectifier VT_D. The center-tapped secondary of T_3 is energized by two primaries, one in each thyratron anode circuit, with polarity such that the unidirectional pulses of current in the two primaries induce an alternating current in the secondary. This secondary circuit is loaded by a resistor to build up the voltage, which is then rectified by VT_D.

With the junction of R_9 and R_{18} connected to the negative side of the armature, an adjustable negative voltage proportional to armature current can be obtained from R_{18} for R_{16}. Now as armature current increases with load, the lower end of R_{16} becomes more negative. This action tends to make the grid voltage of VT_A more negative, which advances the firing point of the thyratrons and raises the armature voltage. By adjusting R_{18} to give correct compensation for a change in armature IR drop, almost constant speed with changing load can be obtained.

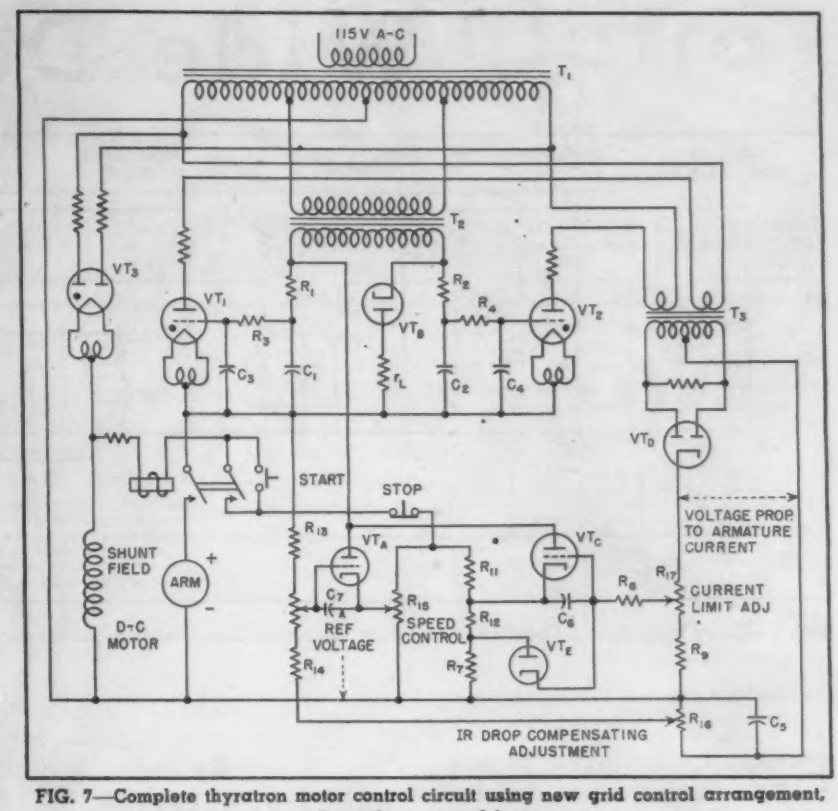

FIG. 7—Complete thyratron motor control circuit using new grid control arrangement, with auxiliary control features

Current Limit Control

To the simple motor speed control just described can be added controls responsive to other functions. Since VT_A is biased off to turn on the thyratrons, and is turned on to turn off the thyratrons, it can be paralleled with another similar tube which is normally biased off. This leaves VT_A normally in control, although the second tube can be turned on by some other signal to retard the firing point of the thyratrons regardless of the speed signal.

In Fig. 7 such a parallel tube, VT_C, is shown connected to limit the load current. The cathode of VT_C is connected to a fixed reference voltage and the grid is connected to a positive voltage proportional to armature current. As long as this voltage is appreciably less than the reference voltage, VT_C is biased off and has no effect on the control of the thyratrons. As before, VT_A serves to maintain constant motor speed.

If the motor is called upon to accelerate to a higher speed, or the load on the motor is increased to the point where the increasing armature current makes the grid voltage of VT_C approach the reference voltage in magnitude, VT_C conducts and retards the firing point of the thyratrons sufficiently to keep the armature current very nearly constant. The current limit may be set at any desired value by potentiometer R_{17}.

The current-limit feature is useful for three reasons: (1) it holds the starting current of the motor below the commutating limit; (2) it limits armature current to protect the thyratrons and assure operation within their rating; (3) it limits the maximum torque the motor can transmit to its driven load.

In the circuit of Fig. 7, grid-cathode capacitors and grid resistors suppress the high ripple component at the grids of VT_A and VT_C. However, this resistance and capacitance in the grid circuit of VT_C slows the response of the tube to a sudden rise in armature current. Vacuum diode VT_B counteracts this by preventing the grid of VT_C from going more negative than slightly below the cutoff value. Now if armature current rises suddenly, the grid-to-cathode voltage need change only a small amount in order for the current limiting control to take over.

Additional Controls

Other control tubes can be added to the thyratron grid control circuit in the same manner as the current-limit tube. They may be used to control the thyratron output in response to any function that can be converted to a direct voltage of sufficient magnitude. Since the control tube requires about 2 volts change to shift the firing point of the thyratrons over the full range, the signal voltage must be appreciably greater than this. The larger this signal and its corresponding reference voltage can be made, the smaller will be the load droop of the control.

Wide Deviation

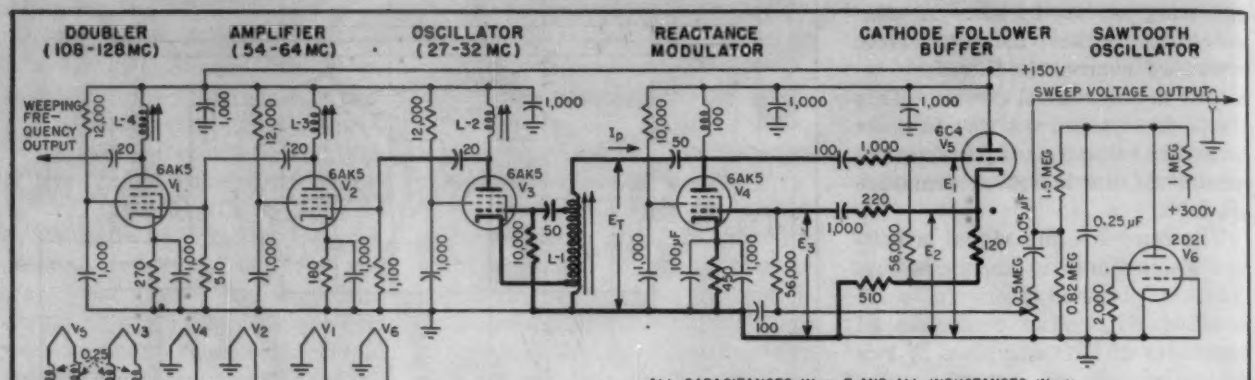

FIG. 1—Heavy lines show a-c portions of reactance modulator. Complete diagram shows basic circuit incorporated in test equipment

FREQUENCY-MODULATED OSCILLATORS having large deviation are frequently needed for testing. To meet such a requirement, the reactance tube modulator has been modified to provide a larger linear sweep than has heretofore been obtainable from it. Although the reactance tube as a frequency modulator is well known,[1,2] only one report has discussed the problem of obtaining maximum deviation at high frequencies.[3] The equipment for which this modulator was designed required a linear 20-mc sweep at 118 mc. Such systems as beating oscillators and motor-driven variable capacitors were unsuitable due to weight, space, output voltage, and variable sweep-width requirements. With conventional reactance tubes, as well as in this modification, the percent deviation decreases with increasing center freqency. However, in the circuit to be described, the required percent deviation could be obtained at a frequency that could conveniently be multiplied to 118 mc, whereas it could not with the others.

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Development of Circuit

Essentially, a reactance modulator consists of a resonant circuit of constant elements to which a controllable reactance is added in parallel. Thus, if the resonant frequency of the constant elements is f_0, the change of frequency Δf when the inserted reactance is inductive is

$$\Delta f = f_0 [(1 + L_{TANK}/L_{ADDED})^{1/2} - 1]$$

and when the inserted reactance is capacitive, it is

$$\Delta f = f_0 [1 - 1/(1 + C_{ADDED}/C_{TANK})^{1/2}]$$

Either case requires that the fixed reactances be as large as possible (large L and small C) and that the added reactance be as small as possible for maximum $\Delta f/f_0$.

With these requirements in mind, the modulator, shown by heavy lines in Fig. 1, was developed. An electron coupled oscillator was employed to permit taking output from the circuit without capacitively loading it. In addition, a cathode follower buffer was inserted between oscillator and reactance tube; the input capacitance of the triode cathode follower could be made appreciably less than that of any high-transconductance reactance tube. Thirdly, an autotransformer connection from the oscillator circuit was employed to reduce the reflected impedance from the reactance tube. Furthermore, all stray capacitances were eliminated from the oscillating circuit, tuning being done by a variable polyiron slug.

Curve B of Fig. 2 shows the deviation obtained by this circuit. However, only 60 percent of the total deviation was in the linear portion of the frequency vs control voltage characteristic, as shown in Fig. 3. By operating the oscillator at a fundamental of 29.5 or 39.3 mc and multiplying, it was possible to obtain the 20-mc deviation at 118 mc. Of course, the necessity of loading or using band pass circuits made multiplication difficult. The electron-coupled oscillator was advantageous because it permitted multiplying in the output.

Analysis of Circuit

Two phasing networks, one before and one after the cathode follower, are used, tube input capacitance forming the reactive legs. If the transmission of the cathode follower is assumed to be $0.6/\underline{0°}$, the vector diagram of the voltages is as shown in Fig. 4, so that the reactive modulator plate current I_{PR} is

$$I_{PR} = g_m E_T (0.6/\underline{0°}) \cos \phi_1 \cos \phi_2 \cos \phi_3$$

and the sum of the angles ϕ_1, ϕ_2 and ϕ_3 is $\pi/2$. By partial differ-

Reactance Modulator

Operating principle and design procedure for obtaining maximum deviation from reactance tube frequency modulator. Use of cathode follower minimizes shunting of the oscillator. A typical test oscillator is described and a universal design chart is developed

entiation, it can be shown that maximum I_{PR} occurs when each of these three angles is $\pi/6$, at which condition I_{PR} is approximately $0.4g_mE_T$. However, because there is a component of I_P in phase with E_T, resistive loading will occur, which will vary with frequency. By properly proportioning the R-C phasing networks this loading can theoretically be eliminated (when $\phi_1 + \phi_3 = \pi/2$; $\phi_3 = 0$ and $I_P = I_{PR}$).

Due to secondary effects not considered, it is doubtful if this ideal condition can be attained. In practice, cut-and-try was used to obtain the maximum frequency deviation compatible with the permissible resistive loading. To be able to evaluate the closeness with which the optimum condition is approached, the theoretical deviation can be determined prior to adjusting the circuit. Because maximum I_{PR} is approximately $0.4g_mE_T$, the minimum added reactance is

$$E_T/I_{PR\ MAX} \approx 2.5/g_m$$

and the minimum added inductance is

$$L_{2\ MIN} \approx 2.5/2\pi f_0 g_m$$

If we define a constant

$$K = L_{TANK}/L_{2\ MIN} \approx g_m/5\pi f_0 C_{TANK}$$

and suppose g_m to have a range of 20 to 1 with variation in reactance tube control voltage, we get by subtracting

$$\Delta f = f_{MAX} - f_{MIN} = f_0\,[(K+1)^{1/2} - (1 + K/20)^{1/2}]$$

From this result the dimensionless ratio $\Delta f/f_0$ has been plotted in Fig. 5 to provide a ready method of computing theoretical maximum deviation for a given center frequency for any type tube.

Application of Circuit

To verify this theory, operation of a practical adaptation of the circuit was studied. Using g_m = 5,000 μmhos and C_{TANK} = 13.5 pf (checked in actual circuit) for a 6AK5 oscillator, 6C4 buffer, and 6AK5 reactance modulator, curve A for Fig. 2 was obtained; curve B is the actual performance curve. The maximum obtainable Δf from a conventional triode oscillator and reactance tube combination[3] is shown as curve C. These curves represent the maximum Δf, not the range of linear frequency vs control voltage response.

Numerous tests made with this circuit indicate that tube replacement is not critical, although a 6AK5 reactance tube of definitely low g_m does reduce the sweep. Control of the sweep range is easily accomplished by a potentiometer between saw tooth oscillator and reactance tube control grid.

The circuit can be adapted to other uses with or without the multipliers. It has application in a panoramic receiver as the sweep oscillator, as a sweeping oscillator for i-f amplifier alignment, and as a wide band noise generator.

The author is appreciative of valuable criticism and assistance given by numerous engineers of the Airborne Instrument Laboratory. In particular, M. T. Lebenbaum helped during design and construction of the oscillator and by his constructive review of this paper. Opinions and assertions contained herein are the author's and are not to be construed as official or reflecting the views of the Navy Dept. or the naval service.

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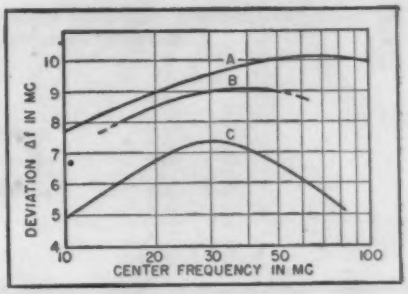

FIG. 2—Comparison of modulator deviations

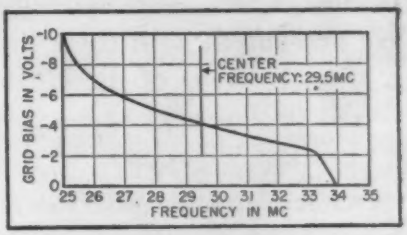

FIG. 3—Curve shows linearity of modulator

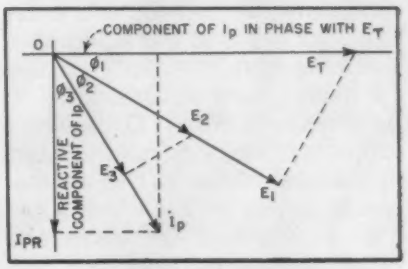

FIG. 4—Voltage vectors; see text and Fig. 1

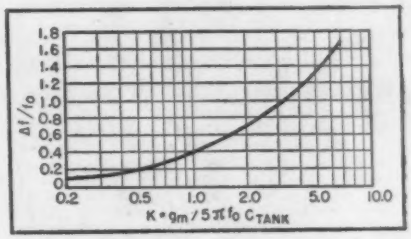

FIG. 5—Knowing circuit constants, one can find maximum deviation from this chart

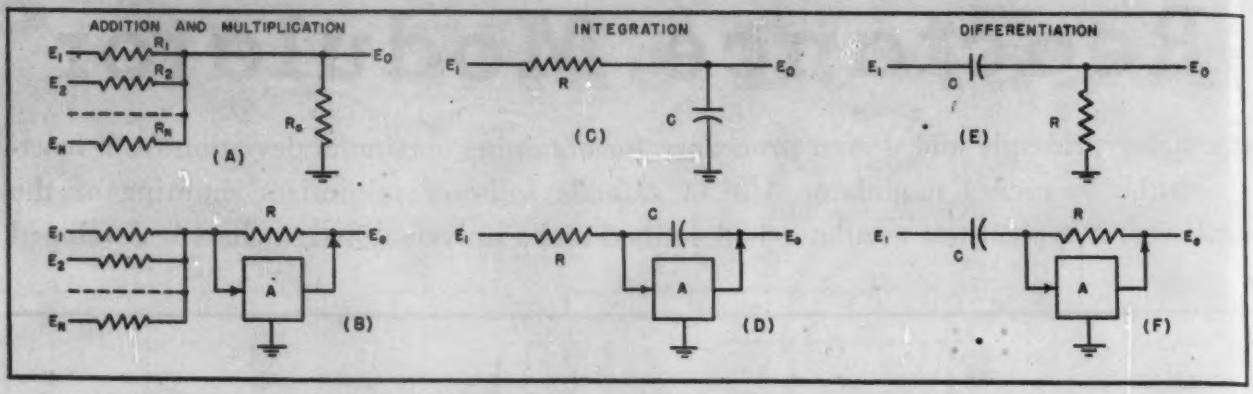

FIG. 1—Basic forms of computing elements are electrical networks; incorporating amplifiers greatly improves their performance. In combination, these elements form computers for solving linear differential equations

Elements of D-C

Design criteria of simple circuits for adding, multiplying, integrating and differentiating are presented, with their limits of accuracy. Operating principles and types of applications of direct-current electrical analog computers are summarized

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ANALYSIS of many engineering problems in both electronic and other fields frequently leads to systems of ordinary linear differential equations with constant coefficients. These and other equations can be solved quickly by electronic computers. Such devices are finding growing application in three major forms: (1) as direct computing tools for scientific and engineering offices, (2) as simulators in testing devices whose equations of operation are known but which have not yet been built, and (3) as industrial regulators to solve continuously the equations expressing the desired behavior of the processes or plants under control.

Actually, electronic devices have long been used in these ways. However, looking on them as computers is a fundamental and hence powerful viewpoint for designers. Analyzed in this manner, electronic computers can be classed into two basic types: (1) digital computers using pulsed counter circuits, and (2) analog computers.

This discussion concerns a variety of the latter type in which direct current (or voltage) represents mathematical variables. Such d-c analog computers can be built using conventional electronic techniques and components.

Digital and Analog Computers

Before discussing the elements of analog computers, the distinguishing features of the two types should be summarized. Digital computers are familiar in the form of desk calculators and such electronic digital calculators as the ENIAC and EDVAC. Essentially they are counters operating in discrete steps. Their accuracy, determined by the number of places for which they are built, can be made very great by providing many places; 10 or 20 places are common in large machines.

Most digital computers perform mathematical operations by addition, all other processes being reduced to combinations of additions. For example, multiplication is performed by repetitive additions, and integration is by summation; converging series can be used in place of trigonometric functions. The fullest utilization of digital computers is obtained in working problems that require complex repetitive operations of high accuracy. Programming facilities are a necessary part of these computers to minimize the number of operating units and to control the sequences of computation.

In contrast, analog computers, such as a-c calculating boards, differential analyzers and slide rules

This article is based on Report 5256-2061, Electronic Solution of Differential Equations, prepared by the author while with Sperry Gyroscope Co., Great Neck, N. Y. The author is grateful to Sperry and in particular to W. L. Barrow, Chief Engineer, for making publication possible. Due to classification of much associated material, it is regretfully impossible to credit individuals and organizations with earlier work on d-c analog computers.

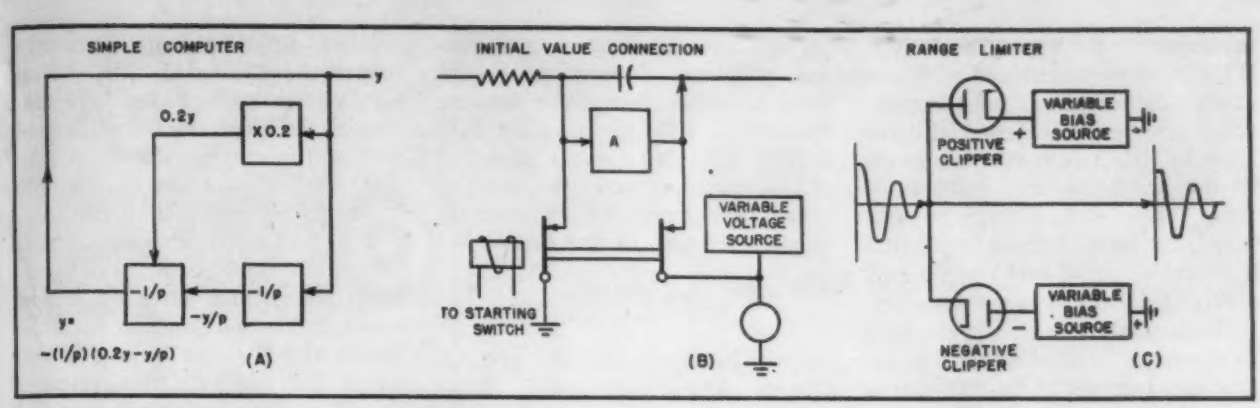

FIG. 2—Computer is connected (A) to perform operations indicated by equation. Before computation starts, initial conditions are introduced (B). Clipper diodes (C) can be used if any variables are limited in range

Analog Computers

operate continuously. In this respect electronic analog computers use techniques similar to those conventionally used in communications, whereas digital computers use techniques similar to those in pulse modulation systems. The accuracy of analog computers is determined by the total available dynamic range and the noise and instability of the circuits. These computers perform mathematical functions in directly analogous fashion, not resorting to arithmetical substitutes. The computing elements have to be continuously connected to each other in the order required by the equation being solved.

The necessity of reducing mathematical operations to arithmetical ones requires considerable planning before a digital computer can handle a problem. Also, because the indirect computations must usually be carried to more places than are required in the final result, the computing elements must have capacity for dealing with large numbers. Consequently, electronic digital computers find their greatest utility in large-scale computation projects. Because they operate by gated pulses, noise and drift in the circuits can be prevented from interfering with the results. By performing computations by alternate methods errors can be detected and evaluated.

On the other hand, d-c analog computers operate continuously. Drifts in one section can thus be passed to succeeding sections, affecting the results. These computers are therefore limited to computations that can be completed before drifts become appreciable. By proper design, instabilities can of course be made as small as necessary, or the more complicated a-c analogs can be used. Furthermore, because little preparation of the problem for the computer is necessary, analog computers are easier to set up. Errors can be determined by repeating each calculation.

Analog computers are therefore more suitable for small-scale problems that do not justify extensive preliminary planning. Being both easier to construct and to operate, they are suited to computations that are too extensive to be undertaken manually but not so elaborate as to justify using the facilities of a computation laboratory. Because the parameters of the problem can be easily changed, electronic computers are useful in investigating the effects of variations of controllable constants in design problems.

NEW TOOLS

Creative engineers are frequently hampered by lengthy routine calculations. High-speed electronic computers can perform these calculations.

There are two types of computers: digital and analog. Although digital computers are capable of higher accuracy and of performing more complex operations, analog computers—the elements of which are described in this article—are simpler to construct and to set up.

In effect, electronic analog computers replace engineers' slide rules, providing tools for performing more operations faster and with about the same accuracy

Establishing Analogs

In analog computers, physical quantities such as voltages that can be varied and measured conveniently are made to obey differential equations identical to those of the original problem. The magnitudes and time scale of the analogous quantities can be reduced or increased to facilitate their measurement.

By comparison to digital computers, analog computers, whose accuracies need not be too great for most applications, are often strikingly simple. The practical im-

portance of d-c analog computers is their low cost combined with ease of application. They solve complicated systems of differential equations by using such simple circuits as d-c amplifiers and potentiometers. These elements can be combined to form extremely flexible differential analyzers or highly specialized control computers.

When combining circuit elements to form an analog computer, the first step is to set up the differential equations to be solved. Then computing elements corresponding to the mathematical operations to be performed are interconnected to duplicate the indicated manipulations. Initial conditions are set into the machine and the solution obtained by varying the independent parameter. All dependent parameters then vary in accordance with the mathematical operations.

Depending on the physical quantities used to represent the mathematical variables and the nature of the computing elements, analog computers can be classed as mechanical, electrical, electromechanical pneumatic and hydraulic. Availability and accuracy of computing elements that perform the required operations determine what type of computer will be used. Many problems, especially in vibration and automatic control engineering, reduce to linear differential equations with constant coefficents of the form

$$F_{j1}(p)x_1 + F_{j2}(p)x_2 + \ . \ . \ . \ + F_{jN}(p)x_N = F_j(y) \qquad (1)$$
$$j = 1, 2, 3, \ . \ . \ .$$
$$p = (d/dy)$$

where $F_{jk}(p)$ are real polynomials in p. Computing elements necessary for solving such an equation are devices that (1) multiply a variable by a constant, (2) form the sum or difference of two variables, (3) form the derivative of a dependent variable with respect to the independent variable, and (4) generate the functions of the independent variable. Repeated operations with these elements will solve all problems that can be expressed in the foregoing form.

Computer Considerations

Before describing elements that perform these operations and analyzing their accuracies, some general problems of computer design need consideration. Both because mechanical differentiators are difficult to build and because electrical differentiators tend to amplify noise, the foregoing equation is usually reduced to the form

$$f_{j1}(1/p)x_1 + f_{j2}(1/p)x_2 + \ . \ . \ . \ + f_{jN}(1/p)x_N = (1/p^n)f_j(y) \qquad (2)$$

in which differentiations are replaced by integrations. Thus integrators are important elements of most analog computers.

The independent variable y has to be fed to all integrators, differentiators, and function generators as well as to the output recorders of the computer. This common drive by the independent variable can be provided simply by choosing actual time (measured on a rate that may be scaled up or down to facilitate the computation) as the independent variable. Then all differentiations and integrations take place with respect to time.

If a device that multiplies two variables is added to the above computing elements, the more general differential analyzer is produced. The versatility and ability of any computer depends on the number of computing elements.

If the time scale is that of actual time, the parameters vary synchronously with those of the physical system whose differential equation is being solved. In such a case, parts of the system can be incorporated into the analog computer. The computer then simulates the remaining parts of the original system and can be used to test the incorporated parts. For example, the analog computer can be used to test an autopilot in the shop. The computer solves continuously the flight equations of the aircraft for which the autopilot is intended. The autopilot supplies the input to the computer. The computer simulates the responses of the aircraft, and feeds them back to the autopilot. Other regulators can be studied in the same manner.

The d-c analog computer represents the dependent variables by direct voltages that vary with time, which is the independent variable. In their simple form, as discussed here, these computers can solve ordinary differential equations with constant coefficients. The necessary elements are adders, integrators, or differentiators, and devices that multiply a variable by a constant, called constant multipliers. It should be noted that the integrating and differentiating circuits used in d-c analog computers necessitate using time (on a convenient scale) as the independent variable. Ohm's and Kirchhoff's laws afford means for adding direct voltages as well as for multiplying them by constants; capacitors accumulate voltage and so form the basis for integrating with respect to time. Stable feedback amplifiers counteract the attenuations inherent in these processes.

Algebraic Operations

If M input voltages E_1, E_2, . . . E_M are applied to the inputs of the summing or averaging network of Fig. 1A, the output voltage E_o is

$$E_o = R_o \sum_1^M \frac{E_k}{R_k} \left[R_o \sum_1^M \frac{1}{R_k} + 1 \right]^{-1} \qquad (3)$$

so that the circuit is useful for computing expressions like

$$A_1x_1 + A_2x_2 + \ . \ . \ . \ A_Mx_M \qquad (4)$$

if the voltages E_k are made to correspond to the variables x_k. Because of the factor on the right of Eq. 3, however, it is difficult to calibrate the resistances R_k in terms of the coefficients A_k if the latter are to be controllable parameters. Equation 3 simplifies to

$$E_o \approx R_o \sum_1^M \frac{E_k}{R_k} \qquad (5)$$
$$\text{for } R_o \sum_1^M \frac{1}{R_k} << 1$$

in which case changing the coefficients is easier, but the ranges of the coefficients $A_k = R_o/R_k$ and the impedance ratio between input and output are severely limited.

These drawbacks are overcome by the summing amplifier of Fig. 1B, which is widely used in d-c and a-c servomechanisms. The output voltage is

$$E_o = -R_o \sum_1^M \frac{E_k}{R_k} \times$$

$$\left[\frac{-A}{1-A+R_o\sum_1^M\frac{1}{R_k}}\right] \qquad (6)$$

The gain A of the amplifier must be negative otherwise the circuit is unstable. If the amplification is large, the output is practically independent of the gain, and Eq. 6 simplifies to

$$E_o = -R_o\sum_1^M\frac{E_k}{R_k} \qquad (7)$$

$$\text{for } \frac{R_o}{A}\sum_1^M\frac{1}{R_k} \ll 1,\ |A| \gg 1$$

which can be used to compute the output in actual installations.

Because Eq. 7 is the one usually used, it is important to know the error introduced by the approximation. From Eq. 6 and 7, one finds that if the approximation of Eq. 7 is to be within P percent of the exact result of Eq. 6, then it is necessary that

$$\frac{1}{A-1}\left[1+\frac{A}{A-1}R_o\sum_1^M\frac{1}{R_k}\right] \leqq \frac{P}{100} \qquad (8)$$

or approximately

$$\frac{R_o}{A}\sum_1^M\frac{1}{R_k} \leqq \frac{P}{100} \qquad (9)$$

$$\text{for } \frac{PA}{100} \gg 1$$

or, if the maximum value of R_o/R_k is R_{MAX}

$$MR_{max} \leqq \frac{PA}{100} \qquad (10)$$

$$\text{for } \left|\frac{PA}{100}\right| \gg 1$$

These last two equations hold exactly if the summing circuit is calibrated. However, these error considerations must be observed in designing computers.

Negative feedback amplifiers are also used as phase inverters whenever negative quantities must be introduced into the computer. They can also be used to sum and to multiply by constants at the same time. Addition can also be performed in the computer at the input of the integrating amplifiers described below. Multiplication can be performed in either the summing or integrating amplifiers by

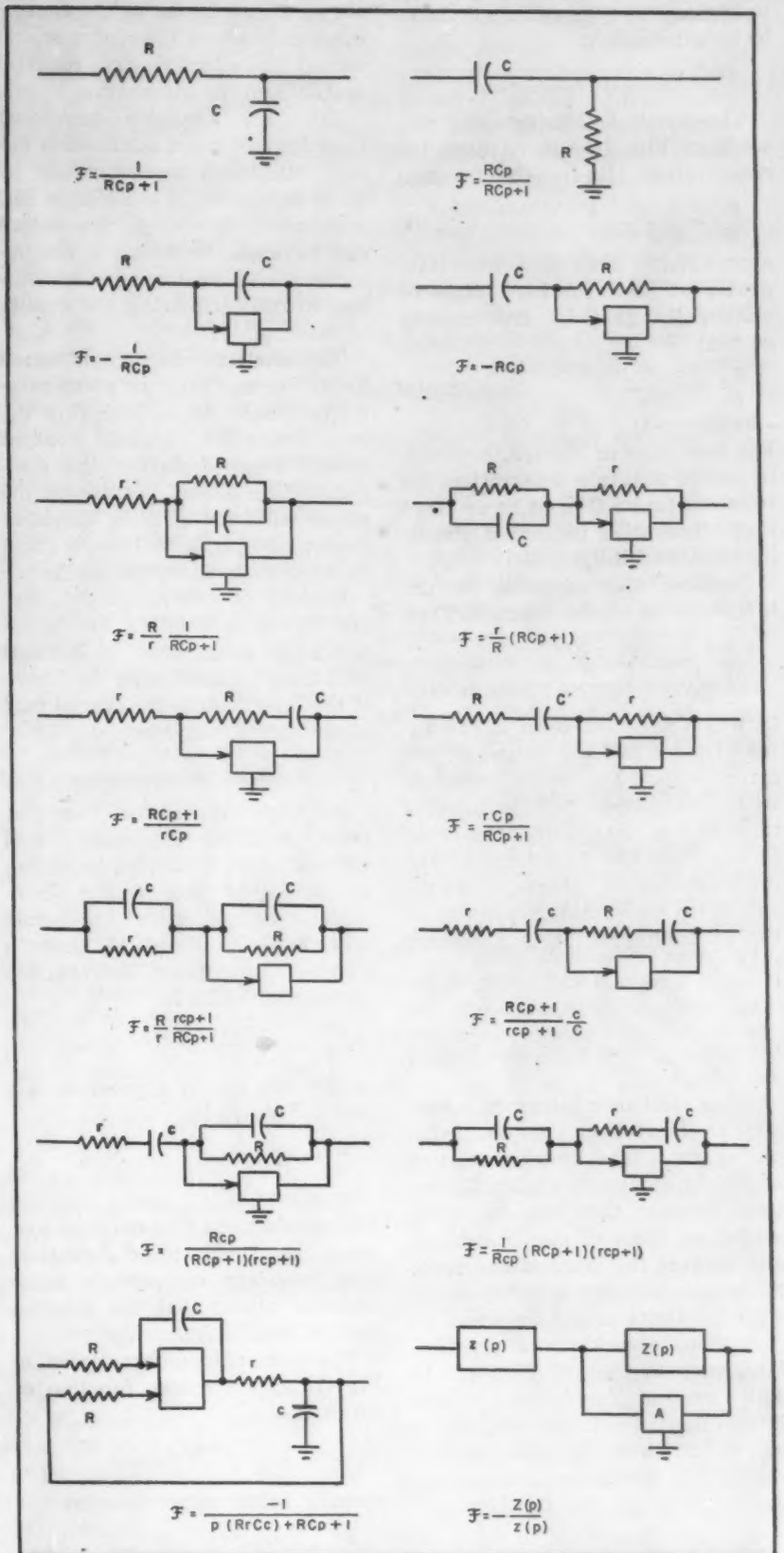

FIG. 3—Combinations of resistors, capacitors and high-gain direct-current amplifiers provide the electrical equivalent of mathematical transforms. Inductors are rarely used in computers because they have more loss than can be tolerated in this application. Computers for special purposes employ appropriate circuits to perform frequently recurring manipulations; more general computers use circuits, such as the two next to the top, that perform basic operations

potentiometer-type voltage dividers or by attenuators.

Electronic Integration

The simple R-C integrating network of Fig. 1C can be used for computation. Its transfer function

$$\frac{E_o}{E_1} = \frac{1}{RCp+1} \qquad (11)$$

approximates that of a true integrator at least for high rates of voltage change (high frequencies) so that

$$\frac{E_o}{E_1} \approx \frac{1}{RCp} \qquad (12)$$
$$\text{for } RCp >> 1$$

For low rates of change, however, to secure accurate integration the time constant RC must be so large that attenuation in such a circuit becomes prohibitive.

Consider the response of the integrator to a step function. Then

$$E(t) = 1 - \exp(-t/RC) = \left[\frac{t}{RC}\right] - \left[\frac{t^2}{2(RC)^2} \pm \ldots\right] \qquad (13)$$

in which the first term is the integral term and the second is the error term. The error increases with time; however, if the integral term is less than unity, the error is less than the first term of the error expression. Hence, if the result is to be within P percent of the true integral, it is necessary that

$$t_{MAX} \leq \frac{PRC}{50} \qquad (14)$$

Computing time must be limited accordingly.

Other electronic integrators have similar limitations on the computing time. The limiting relation of Eq. 14 applies to all input functions because they can be represented as sums of step functions, and because the integral and error terms change sign simultaneously with the input step functions.

A more accurate and practical integrator is that of Fig. 1D in which an amplifier is used. Good integration is obtained with little or no attenuation and smaller values of resistance and capacitance. The transfer function is

$$\frac{E_o}{E_1} = \frac{A}{(1-A)RCp+1} \qquad (15)$$

which can be simplified to

$$\frac{E_o}{E_1} \approx \frac{-1}{RCp} \qquad (16)$$
$$\text{for } |A| >> 1, |ARCp| >> 1$$

showing that, as far as the approximation to a true integrator is concerned, the effective time constant is ARC and the attenuation is only $1/RC$. The available computing time for any given attenuation has been multiplied approximately by A, as compared to the simple R-C integrator. Moreover, the output can be made to match a low-impedance load, such as a potentiometer, without impairing the quality of integration.

The electronic integrator has a limitation that must be given careful consideration in designing the computer. The highest output voltage reached during the computing time should not exceed the range within which the amplifier output tube performs linearly; that is, saturation must be avoided.

Because of the nature of integration, it is possible for initial errors in integration to increase with time. Accordingly, the design of the integrator is the crucial part of the entire computer design.

Electronic Differentiation

Although integrators are of great practical importance, and differentiation is avoided in setting up equations for analog computers, differentiators are sometimes needed. Figure 1E shows a simple differentiator the transfer function of which is

$$\frac{E_o}{E_1} = \frac{RCp}{RCp+1} \qquad (17)$$

so that the circuit approximates a true differentiator

$$\frac{E_o}{E_1} \approx RCp \qquad (18)$$
$$\text{for } |RCp| << 1$$

The requirement that the time constant be small to differentiate high-frequency components satisfactorily means that the attenuation is prohibitive.

The electronic differentiator of Fig. 1F, the transfer function of which is

$$\frac{E_o}{E_1} = \frac{RCp}{[(1-A)/A] + [(RC/A)p]} \qquad (19)$$

gives a better approximation

$$\frac{E_o}{E_1} \approx -RCp \qquad (20)$$
$$\text{for } \frac{RC}{p} << 1$$

and can be analyzed similarly to the integrator.

The d-c analog computer consists of banks of these basic elements arranged so that they can be interconnected, usually by plugging connectors, as required by the equations to be solved. Calibrated potentiometers are provided for setting in constants, and synchronously driven tapered potentiometers are used to provide special functions. As in designing all electronic systems, stability and interstage coupling, especially through common power supplies, need careful attention.

Setting Up the Computer

In solving equations on d-c analog computers that use such elements as these, a special procedure must be followed, and auxiliary circuits may be necessary. To illustrate the procedure, consider setting up the computer for solving the differential equation

$$p^2y - 0.2\,py - y = 0 \qquad (19)$$

which, for use in an analog computer, is equivalent to

$$y = -(1/p)(0.2y - y/p) \qquad (20)$$

and so is handled in this form to use integrators rather than differentiators. The voltage corresponding to y appears at the upper right in the computer circuit shown in Fig. 2A. The diagram shows how voltages $0.2y$ and $-y/p$ are formed by a potentiometer and an integrator. These two voltages are then applied to a summing integrator to complete the solution for y. The voltage y is fed back so that it must vary according to the given differential equation.

In most problems, initial values for the dependent variables are specified. To provide for setting these initial voltages at the beginning of each run of the computer, a variable voltage source can be connected across the output of each integrator. While the computer is operating it is impossible to keep the fixed values set up. A variable could not, for instance, have a time rate of change and yet have a fixed value. Therefore the d-c analog computer is made inoperative by grounding the grids or input terminals of all integrators while initial conditions are being set up. To start a run, the amplifiers are disconnected from the initial-value

voltage sources and the grids ungrounded. All this must be done simultaneously for all amplifiers, so a system of relays such as that of Fig. 2B is used.

The number of given initial conditions must always equal the number of integrators used for the particular problem, and each integrator must be set to the corresponding initial-condition voltage before a run. However, summing amplifiers or phase inverters need not be set for the initial conditions corresponding to their initial output voltages, although it may be desirable to set the output of the amplifier that feeds a recorder. The calibrated voltage source by which this is done may be useful for calibrating the recorder.

Initial values are usually given for variables and their derivatives, such as y, dy/dt, ... In many computer setups the integrator output voltages, which have to be set to their initial conditions, may not correspond to y, dy/dt, . . . , but to linear combinations of them, such as $5y + dy/dt$. The corresponding initial voltages must be computed and the integrators set accordingly, using the correct scale factor.

Because the initial value voltage sources have to charge the integrating capacitors, they should have fairly low internal impedance (500 to 1,000 ohms if possible) so that the initial values can be set into the computer without too much time lag.

Limits, Functions and Tables

In certain problems to be solved by d-c analog computers, the values of some of the dependent variables may be limited. For example, in automatic controls the operating range may be restricted by limit stops. Such conditions are a form of nonlinearity that can be taken care of easily by simple analog computers.

The direct voltages representing the nonlinear variables in question are restricted within positive and/or negative limits by diode clippers as shown in Fig. 2C. The diodes have very low impedances for all voltages higher than the biases applied to them. For good limiting, the variable bias limit voltage sources should have low impedance (300 to 500 ohms), because the amplifier outputs have fairly low impedances to ground.

To solve equations such as the one for forced oscillations,

$$F(x/p) = F(t) \qquad (21)$$

on a d-c analog computer, it is necessary to introduce voltages varying with time like the given function $F(t)$. There are many possible methods for generating such function voltages. A direct voltage can be varied in almost any manner with time by using properly tapered potentiometers that are driven by constant-speed motors, or by using linearly wound potentiometers driven by function cams. A graph of the required function can be plotted on an input table, which is moved at a constant speed along the time axis while a stylus follows the curve. The stylus drives a potentiometer to produce the function voltage.

As a rule such complicated function generators are unnecessary. The functions most frequently needed for analyzing frequency response of systems are sine waves. Although designing sine-wave generators is straightforward, it is difficult to generate sinusoidal voltages of the necessary purity at the low frequencies used in most d-c analog computers. Sine waves can be generated electromechanically with rotating tapered potentiometers or by rectifying the output of rotating a-c transformers. Phase shift or heterodyne oscillators can also be used but they are rarely stable enough at the low frequencies involved.

Continuous functions usually contained in mathematical tables, such as hyperbolic functions, can be generated similarly if required.

Outputs and Recorders

The variation with time of the voltages representing the dependent variables can be recorded by electromechanical oscillographs or by recording galvanometers if the components of frequency are below about 100 cps. The choice of the recorder determines the upper limit for the frequencies to be used in the computer.

Because of the low impedances of recording meters, it is necessary to drive them through a d-c impedance transformer such as a compensated cathode follower. The accuracy of most recording devices (2 to 3 percent) is inadequate for large computers; it may be worthwhile to design special servo-driven plotting boards for recording.

In many cases, such as certain oscillation studies, recording the output is unnecessary because the interest is mainly in the rms or average values of the variables. Such averages can be read directly on meters connected to the output of integrators.

Circuits for Special Functions

Many frequently encountered transfer functions can be produced directly using high-gain feedback d-c amplifiers in combinations with several resistors and capacitors. These networks can be used, for example, in servomechanisms to provide delay or anticipation. In computers they perform operations which would otherwise require several of the simpler elements that have been described, and so their use simplifies handling such relations.

Figure 3 shows several such circuits and their approximate transforms obtained if the amplifiers have very high gain. Many such circuits could be devised to correspond to all the functions in a given table of transforms. However, there is a practical limit to the number of such circuits that would prove useful. Most computations encountered in electronic and other branches of engineering can be performed with the computer elements that have been described here.

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TELEPHONE DIAL TESTER

Remote testing of telephone dial speed and pulse length is accomplished with a simple electronic device. D-c voltage proportional to dial speed affects bias on thyratrons that control audible signals sent back over line to indicate slow, correct, or fast operation. Pulse length is similarly checked and indicated

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IN THE OPERATION of an automatic telephone exchange, the characteristics of the telephone dial from which controlling impulses are derived are of importance because the relays and switches are adjusted for optimum response at a given pulse rate. Specifically, the speed of the dial must be such that between 9 and 11 impulses per second are transmitted and these impulses must have an on-off ratio of approximately 2 to 3; that is, the contact make time is 40 percent of the cycle, and the break time is 60 percent of the cycle. For convenience in maintaining a number of telephone dials in proper operating condition, the use of a centrally located test unit is desirable.

The dial tester to be described was developed for use with an industrial plant telephone system to assist in maintaining proper operation of some 400 instruments (telephone dials) without the need for carrying test equipment from instrument to instrument, or the need for removing instruments from their usual locations for test at a central location. The dial tester is not a commercial instrument, nor was it built with the idea of making a commercial instrument of similar characteristics.

The test unit, energized by dialing an appropriate number, returns a tone to the receiver of the instrument being tested, indicating whether the speed is correct, too slow, or too fast. By dialing a different test number, the instrument indicates whether the contact make-break ratio is correct. The apparatus, shown in block form in Fig. 1, is a high-low limit device.

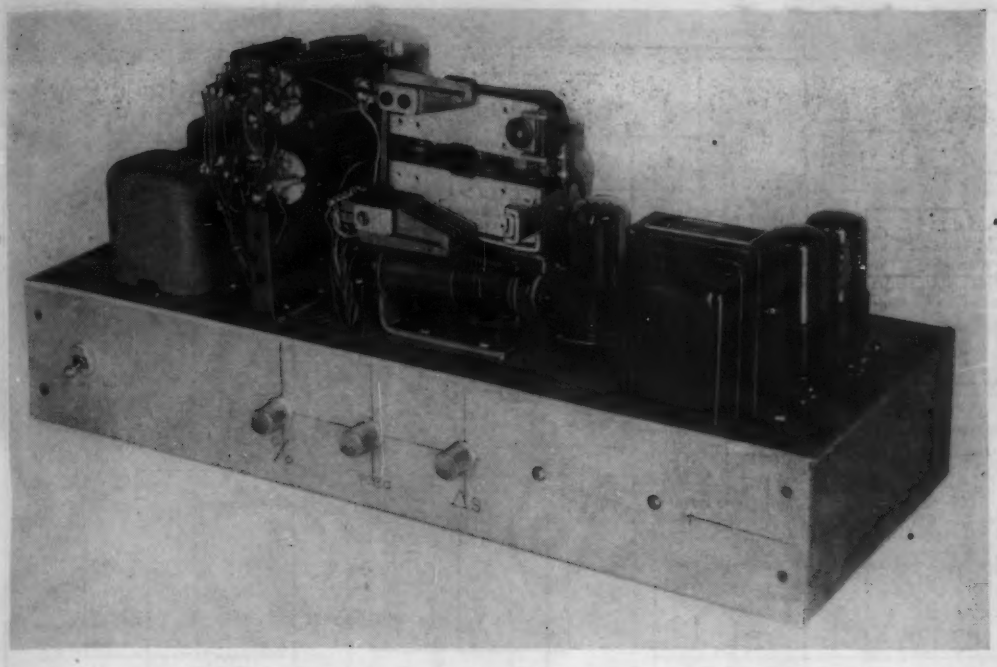
Under-chassis view of the unit complete with regulated power supply

Rate Testing

For speed testing, the dial impulses received over the line from the remote instrument operate a pulse repeating relay that triggers a one-shot multivibrator, once for each received pulse. The output pulses from this circuit have a width and height dependent primarily on the characteristics of the multivibrator circuit, and inde-

CHECKING CONTROL DIALS

Users of telemetering equipment controlled by dial impulses require a convenient calibration and checking standard. The tester described makes it easy to maintain speeds between 9 and 11 pulses per second to which switching is normally adjusted, and in addition allows a check on the ratio of make-and-break time of the cycle



Top-of-chassis view of the dial-speed standard with controls on front apron

pendent of the waveform or width of the incoming pulses. Accordingly, the repetition rate of the multivibrator-derived pulses is the only characteristic that is related to the incoming pulses when this particular portion of the circuit is in use. These pulses are averaged in an RC circuit to produce a smooth direct voltage that reaches a steady state prior to the termination of the 10 test impulses sent to it by the dial. This steady-state direct voltage is used to overcome the peak a-c bias on a pair of thyratrons. The thyratrons are arranged so that one requires a small value of d-c before firing, while the second requires a slightly larger value of d-c before it will fire.

If the dial is running at the correct speed, the d-c bias developed is sufficient to fire one thyratron only. If the dial is running too slowly, the voltage is insufficient to fire either thyratron. If the dial is running too fast the voltage developed is sufficient to fire both thyratrons. In the last case, the thyratrons fire in time sequence since the voltage required to fire one is developed at an earlier time than that required to fire the other.

Each thyratron plate circuit contains a relay coil. An associated locking coil is also provided. Accordingly, when a thyratron fires, its associated relay is energized and locks up. The operation of the relay contacts changes the frequency developed by a local RC oscillator incorporated as part of the apparatus. If a dial is running too slowly, no change in frequency occurs, and a 500-cycle note, which was present at the beginning of the test, remains unchanged.

If the dial is running at the correct speed, between 9 and 11 impulses a second, one relay operates, producing one step in frequency and changing the frequency to 1,000 cycles. If the dial is running too fast, both thyratron control relays operate in sequence, producing two distinct frequency steps, the final frequency present being approximately 1,500 cycles. These frequencies are returned over the telephone line to the receiver of the instrument under test.

Pulse Duration Test

The make-break ratio test circuit operates in a similar fashion, with the exception of the derivation of the d-c control bias for the thyratrons. Prior to the make-break ratio test, the dial speed is set correctly by the speed test described above. Then a different test number is dialed that actuates relays

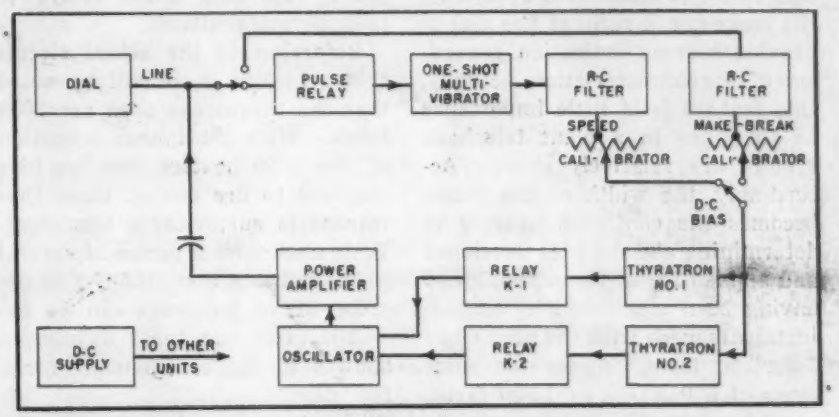


FIG. 1—Block diagram of the combined dial speed and make-break ratio analyzer

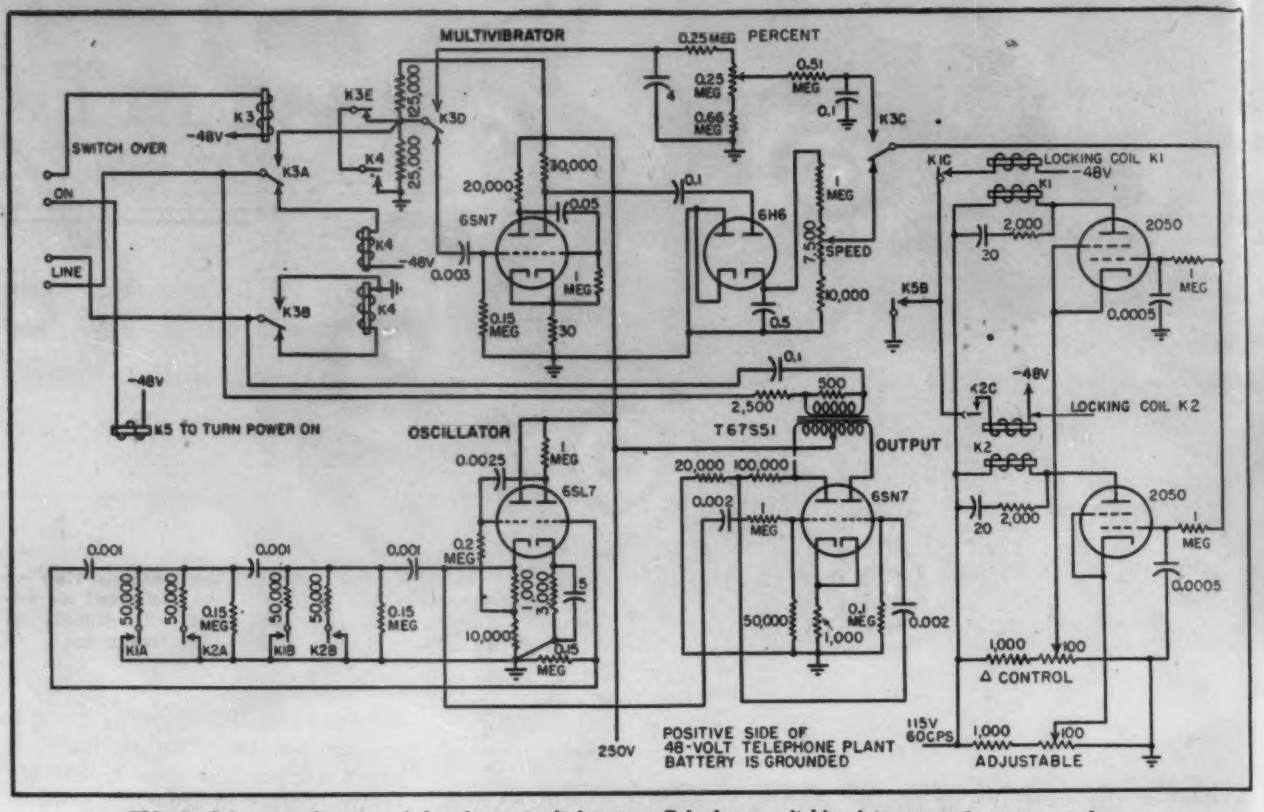


FIG. 2—Schematic diagram of the electronic dial tester. Telephone switching interconnections are not shown

to change the connections to the test unit. These changes omit the multivibrator stage and connect an RC averaging network directly to the incoming line. The pulses received directly from the incoming line are controlled in width by the make-break ratio of the dial under test. Their height is determined by the voltage provided from the regulated power supply in the apparatus and by line attenuation characteristics. Since central exchange apparatus must work with pulses of the same line attenuation, this factor is eliminated by setting the make-break ratio of the dial to provide correct indication regardless of line characteristics. Actually, this feature is of little importance as the lines in a plant telephone system are relatively short. Accordingly, the width of the pulses becomes the controlling factor in determining the d-c bias developed and applied to the thyratron, speed having been eliminated by the adjustments made with the previously described tests. Again the same tones of 500, 1,000, or 1,500 cycles are returned to the instrument over the telephone line to indicate a make-to-break ratio that is too small, correct, or too large.

Circuit Details

The control relays used to actuate the apparatus are arranged so that when the instrument being tested hangs up, the B supply voltage and the a-c plate supply for the thyratrons is disconnected, although the heaters are left in an energized condition. At this time the lock-up circuits of the thyratron plate relays are also de-energized, returning these relays to their normal position.

Referring to the actual circuit shown in Fig. 2, it will be noted that the thyratrons used are 2050 tubes. With continuous operation of the 2050 heaters, the d-c bias required to fire one of these thyratrons is surprisingly consistent. Tests made over a period of several weeks indicate that stability in the order of 75 millivolts can be expected after the tubes have been allowed to age continuously for a few days.

The potentiometers in the d-c bias circuits for the thyratrons, marked PERCENT and SPEED, and the potentiometer marked Δ CONTROL, are used to set the operating points of the thyratrons correctly for the speed, and the make-to-break ratio tests, with the aid of test dials that have been modified to have characteristics at either end of the acceptance band of the apparatus for both tests. Modification of dials for this purpose is performed easily with the aid of an oscilloscope and a calibrated oscillator for speed determination, as well as observation of the mechanical operation of the contacts with angular position of the actuating cam for make-to-break percentage.

The battery connections for the various relays refer to the 48-volt local telephone battery. Relay coils and associated contacts, while physically separated on the diagram, are identified by the same symbol letter and numeral, with additional letters for various multiple contacts present on a single relay. For stability a regulated d-c power supply is used. A regulated a-c supply for the thyratrons is also desirable.

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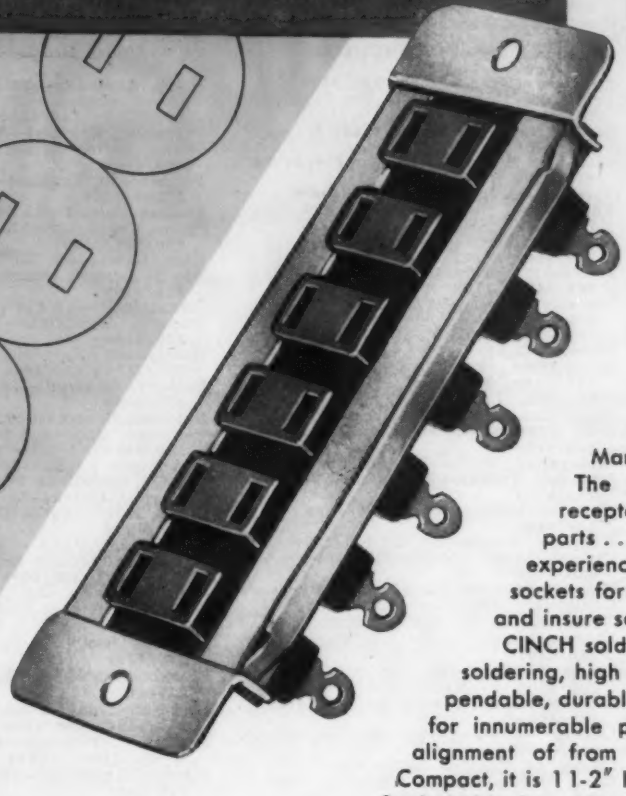
NEW CINCH 110 V. RECEPTACLE

54A 12844 MOUNTING CENTER 1⅛″



Many uses suggest themselves *on sight.* The space saved by this new, 110V AC receptacle . . . the materials in component parts . . . CINCH'S quarter of a century of experience in making exacting *standard* sockets for Electronics . . . recommend it—and insure satisfaction.

CINCH solder coated contacts for easy soldering, high dielectric bakelite—a dependable, durable *space saving* receptacle for innumerable purposes. Obtainable in alignment of from one to six or more. Compact, it is 11-2″ long, 9-16″ wide, and firmly holds the standard blade plug. It is Underwriters approved, and designed for sub or top mounting. Write for samples and further detail.

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World Power Line Data

Predominant voltages and frequencies in 165 foreign cities having over 200,000 population, for designers of electronic equipment intended for export. Most common power outside U. S. is 50 cycles at 220 or 230 v. Values of d-c voltages are bold-face

Adelaide, Australia—3ϕ 50c 210/420v
Agra, India—3ϕ 50c 230/400v
Ahmedabad, India—3ϕ 50c 230/400v
Alexandria, Egypt—1ϕ 50c 115/230v
Algiers, Algeria—3ϕ 50c 115/200v
Altona, Germany—3ϕ 50c 220/380v; **220/440v; 110v**
Amritsar, India—3ϕ 50c 230/400v; **220/440v**
Amsterdam, Netherlands — 3ϕ 50c 220/380v
Amoy, China—3ϕ 60c 110/220v
Antwerp, Belgium—3ϕ 50c 115/200v
Athens, Greece—3ϕ 50c 220/380v
Auckland, New Zealand—3ϕ 50c 230/400v; **230/460v**
Avellaneda, Argentina—3ϕ 50c 220/380v
Bagdad, Iraq—3ϕ 50c 220/380v; **220/440v**
Baku, Russia—3ϕ 50c 120/210v
Bangkok, Siam—3ϕ 50c 110/220v
Bangalore, India—1ϕ 60c 220v
Batavia, Java—3ϕ 50c 127/220v
Belfast, Ireland—3ϕ 50c 230/380v
Belgrade, Yugoslavia—3ϕ 50c 220/380v & 120/206v
Benares, India—3ϕ 50c 230/400v
Berlin, Germany—3ϕ 50c 220/380v; **220/440v**
Birmingham, England—3ϕ 50c 230/400v; **220/440v**
Bochum, Germany—3ϕ 50c 220/380v & 127/220v
Bogota, Colombia—3ϕ 60c 150/260v
Bologna, Italy—3ϕ 42c 127/220v
Bombay, India—3ϕ 50c 230/400v; **230/460v**
Bordeaux, France—3ϕ 50c 115/200v; **110v**
Bradford, England—3ϕ 50c 230/400v; **220/440v**
Bremen, Germany—3ϕ 50c 230/400v & 125/216v
Breslau, Germany—3ϕ 50c 220/380v
Brisbane, Australia—3ϕ 50c 240/415v
Bristol, England—3ϕ 50c 210/365v; **250/500v**
Brno, Czechoslovakia—3ϕ 50c 110/220/380v
Brussels, Belgium—3ϕ 50c 110/190v
Bucharest, Roumania—3ϕ 50c 120/208v & 110/190v
Budapest, Hungary—3ϕ 50c 220/380v; **110v**
Buenos Aires, Argentina—3ϕ 50c 220/380v; **220/440v**
Cairo, Egypt—1ϕ 40c 100/200v; **110v**
Calcutta, India—3ϕ 50c 230/400v; **225/450v**
Cape Town, Union of South Africa—3ϕ
Canton, China—3ϕ 60c 220/380v & 110/190v
Cardiff, England—3ϕ 50c 200/230v; **200/400v**
Catania, Italy—3ϕ 50c 150/260v
Cawnpore, India—3ϕ 50c 230/400v; **225/450v**
Chemnitz, Germany—3ϕ 50c 120v
Chungking, China—3ϕ 50c 220/380v
Colombo, Ceylon—3ϕ 50c 230/400v; **220/440v**
Copenhagen, Denmark—3ϕ 50c 220/380v & 127/220v; **220/440v**
Cordoba, Argentina—3ϕ 50c 220/380v
Croydon, England—3ϕ 50c 230/400v; **230/460v**
Dairen, Kwantung province—3ϕ 50c 110/220v
Delhi, India—3ϕ 50c 200/400v; **220/440v**
Dortmund, Germany—3ϕ 50c 220/380v & 125/216v; **220/440v; 110v**
Dresden, Germany—3ϕ 50c 220/380v & 110/220v
Dublin, Ireland—3ϕ 50c 220/380v
Duisburg, Germany—3ϕ 50c 220/380v
Dusseldorf, Germany—3ϕ 50c 220/380v; **110v**
Edinburgh, Scotland—3ϕ 50c 230/400v; **230/460v**
Essen, Germany—3ϕ 50c 220/380v; **110v**
Florence, Italy—3ϕ 50c 150/260v; **150/300v**
Foochow, China—3ϕ 50c 220/380v
Frankfort, Germany—3ϕ 50c 220/380v & 127/220v
Genoa, Italy—3ϕ 50c 150/260v & 127/220v
Glasgow, Scotland—3ϕ 50c 250/440v; **250/500v**
Goteborg, Sweden—3ϕ 50c 120/380v
The Hague, Netherlands—3ϕ 50c 127/220v
Halle, Germany—3ϕ 50c 220/380v; **220/440v**
Hamburg, Germany—3ϕ 50c 220/380v; **220/440v; 110v**
Hankow, China—3ϕ 60c 220/380v; **220/440v**
Harbin, Manchukuo—3ϕ 50c 135/234v
Havana, Cuba—3ϕ 60c 110/220v
Helsingfors, Finland—3ϕ 50c 127/220v; **225/450v**
Hiroshima, Japan—3ϕ 60c 100/200v
Hong Kong China—3ϕ 50c 200/350v
Hull, England—3ϕ 50c 230/400v; **220/440v**
Hyderabad, India—3ϕ 50c 220/380v
Istanbul, Turkey—3ϕ 50c 220/380v & 110/190v
Karachi, India—3ϕ 50c 220/380v; **220/440v**
Kharkov, Russia—3ϕ 50c 110/190v
Kiel, Germany—3ϕ 50c 220/380v; **220/440v**
Kiev, Russia—3ϕ 50c 110v
Konigsberg, Germany—3ϕ 50c 220v
Kyoto, Japan—3ϕ 60c 100/200v
Lahore, India—3ϕ 50c 220/380v; **220/440v**
Leeds, England—3ϕ 50c 230/400v & 200/346v
Leicester, England—3ϕ 50c 240/415v; **220/440v**
Leipzig, Germany—3ϕ 50c 220/380v; **220/440v**
Leningrad, Russia—3ϕ 50c 120v
Lille, France—3ϕ 50c 120/208v; **120v**
Lima, Peru—3ϕ 60c 220v
Lisbon, Portugal—3ϕ 42c 220/380v; 3ϕ 50c 110/190v; **220/440v**
Liverpool, England—3ϕ 50c 230/400v; **230/460v**
London, England—3ϕ 50c 230/400v eventually; many kinds now
Lucknow, India—3ϕ 50c 230/400c; **230/460v**
Llow, Poland—3ϕ 50c 110/220v
Madras, India—3ϕ 50c 250/400v; **225/450v**
Madrid, Spain—3ϕ 50c 120v; **120v**
Magdeburg, Germany—3ϕ 50c 220/380v & 127/220v
Manchester, England—3ϕ 50c 230/400v; **200/400v**
Mannheim, Germany—3ϕ 50c 220/380v & 127/220v
Melbourne, Australia—3ϕ 50c 230/400v; **230/460v**
Messina, Italy—3ϕ 50c 150/260v
Milan, Italy—3ϕ 50c 150/260v; 3ϕ 42c 144/250v
Montevideo, Uruguay—3ϕ 50c 220v
Montreal, Canada—3ϕ 60c 115/230v
Moscow, Russia—3ϕ 50c 120v
Mukden, Manchukuo—3ϕ 60c 110/220v
Munich, Germany—3ϕ 50c 220/380v; **220/440v; 110v**
Nagpur, India—3ϕ 50c 230/400v; **220/440v**
Nanking, China—3ϕ 50c 220/380v
Naples, Italy—3ϕ 50c 150/260v; **220/440v**
Nice, France—3ϕ 25c 110/190v; **110v**
Ningpo, China—3ϕ 50c 220/380v
Oporto, Portugal—3ϕ 50c 220/380v & 110/190v
Oslo, Norway—3ϕ 50c 230v; **230/460v**
Palermo, Italy—3ϕ 50c 150/260v
Para, Brazil—3ϕ 50c 120/240v
Paris, France—3ϕ 50c 110/190v
Peiping, China—3ϕ 50c 220/380v
Pernambuco, Brazil—**220/440v**; 3ϕ 50c 220v
Perth, Australia—3ϕ 40c 240/440v
Piraeus, Greece—3ϕ 50c 220/380v & 200/346v; **230/460v**
Plymouth, England—3ϕ 50c 230/400v
Poena, India—3ϕ 50c 230/400v; **220/440v**
Portsmouth, England—3ϕ 50c 230/400v & 200/400v
Poznan Poland—3ϕ 50c 220/380v
Praha, Czechoslovakia—3ϕ 50c 120/220/380v
Riga, Latvia—3ϕ 50c 120/220/380v
Rio de Janeiro, Brazil—3ϕ 50c 125/216v
Rome, Italy—3ϕ 45c 127/220v
Rosario, Argentina—3ϕ 50c 220/380v; **220/440v**
Rotterdam, Netherlands—3ϕ 50c 220/380v; **220/440v**
Salford, England—3ϕ 50c 230/400v; **230/460v**
Saloniki, Greece—**220/440v**
Santiago, Chile—3ϕ 50c 220/380v; **220/440v**
Sao Paulo, Brazil—3ϕ 60c 120/208v
Sevilla, Spain—3ϕ 50c 127/220v; **110v**
Shanghai, China—3ϕ 50c 200/350v, 220/380v (Int. settlement), & 110/190v
Sheffield, England—3ϕ 50c 200/350v
Singapore, Straits Settlement—3ϕ 50c 230/400v; **230/460v**
Sofia, Bulgaria—3ϕ 50c 220/380v
Soerabaya, Dutch East Indies—3ϕ 50c 110/190v
Stettin, Germany—3ϕ 50c 220/380v; **220/440v**
Stockholm, Sweden—3ϕ 50c 220v; **220/440v**
Stoke-on-Trent, England—3ϕ 50c 240/415v; **220/440v**
Stuttgart, Germany—3ϕ 50c 220/380v & 127/220v; **110v; 220/440v**
Sydney, Australia—3ϕ 50c 240/415v; **240/480v**
Tabriz, Iran—3ϕ 50c 220/380v
Teheran, Iran—3ϕ 50c 220/380v
Tientsin, China—3ϕ 50c 220/380v
Tokio, Japan—3ϕ 50c 100/200v; 3ϕ 60c 100/200v
Toronto, Canada—3ϕ 25c 115/230v
Trieste, Italy—3ϕ 42c 127/220v
Tsinan, China—3ϕ 50c 220/380v & 110/190v
Tsingtao, China—3ϕ 50c 120/200v
Tunis, Tunisia—3ϕ 50c 110/190v
Turin, Italy—3ϕ 50c 127/220v
Valparaiso, Chile—3ϕ 50c 220/380v; **220/440v**
Vancouver, Canada—3ϕ 60c 110/220v
Venice, Italy—3ϕ 42c 127/220v
Vienna, Austria—3ϕ 50c 220/380v
Warsaw, Poland—3ϕ 50c 120/220v
Winnepeg, Canada—3ϕ 60c 120/220v
Zurich, Switzerland—3ϕ 50c 220/380v, 125/220v, & 145/250v; 1ϕ 50c 110/220v & 220/440v

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Data given here was obtained from "World Electrical Markets," a publication of the Electrical Division, Bureau of Foreign and Domestic Commerce, Washington, D. C. Power data for cities not listed here and for entire countries can be obtained by writing to the Bureau. Abbreviations used here are: c—cycles per second; ϕ—phase (single-phase power is of course available where 3ϕ is indicated); v—volts; /—and, signifying both voltages are available.

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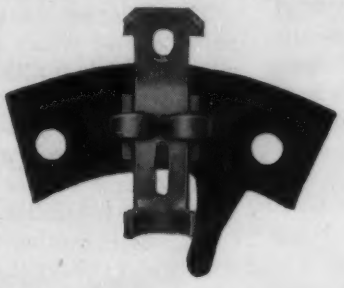

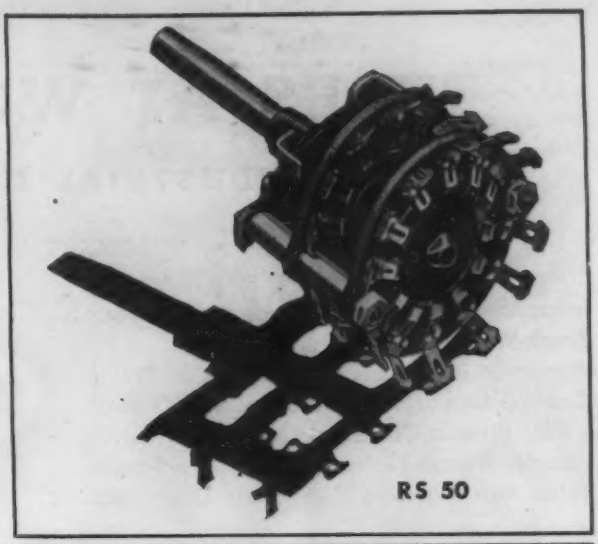

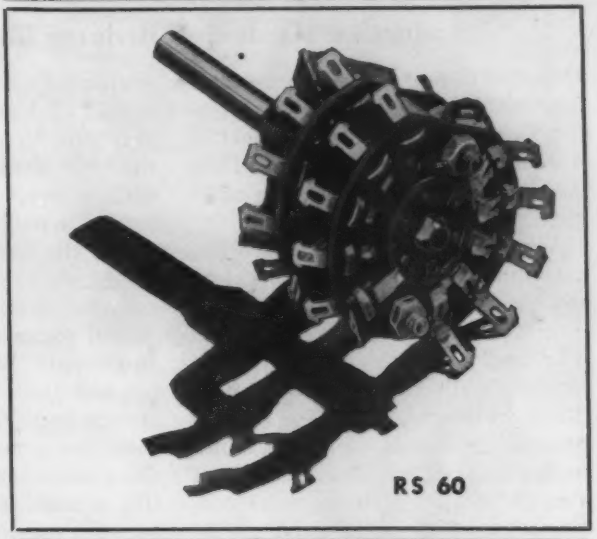

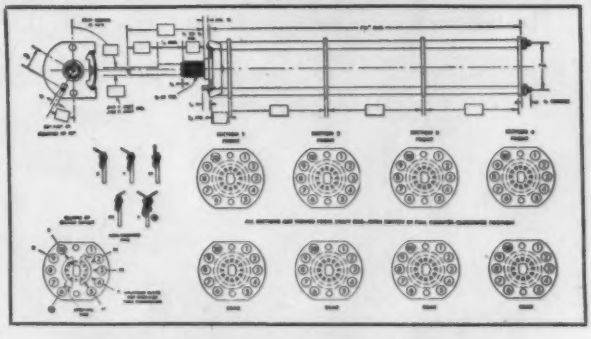

THEY'RE small, they're flexible, they're ruggedly designed. That's the story of the RS 50 and RS 60—two Mallory switches especially designed for radio receiver applications where low torque indexing is required.

An outstanding feature of these switches is the two-point stapling which assures that terminals won't work loose. The terminals themselves are made of heavy spring brass for strength, silver plated, formed for flexibility, insuring low contact resistance.

Many other features are notable too: the improved low-loss phenolic in stator and rotor . . . the star wheel ball indexing with 30° between positions . . . silver-to-silver double wiping contacts . . . where desired the exclusive Mallory silver-indium treatment may be applied to rotor segments permitting higher contact pressure with lower, smooth operating torque and a minimum of contact resistance with extremely low noise level and long life.

The RS 50 is made with from 2 to 10 positions—the RS 60 with from 2 to 5. For more details, write for engineering data folder.

Ask for RS Specification Sheets

Printed on thin paper to permit blueprinting, these sectional drawings indicate standard and optional dimensions—make it easy for you to specify Mallory RS switches built to meet your circuit requirements. Ask your nearest Mallory Field Representative or write direct for a supply.

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P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

TUBES AT WORK

Including INDUSTRIAL CONTROL

Edited by VIN ZELUFF

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Truck-Wheel Balancer 134
Electronic Timer 136
Construction of Shielded Room in VHF Field 150
X-Ray Speeds Chemical Comparisons 158
Polarity Response from Tuning Eye Tubes 162
Television Monitors Dangerous Operation 168

Induction Hardening Reduces Blade Cost

USE of a radio-frequency generator has enabled Hancock Manufacturing Company to reduce the cost of hardening grass shear blades from 2.5 cents each to 1 cent. In addition, the quality is improved.

When blades were hardened throughout using the previous method 50 percent of the blades required individual straightening. The product was satisfactory, but closely. With automatic work handling equipment, induction heating produces 900 blades per hour, eliminating distortion and consequent straightening by heating the cutting edge of the blade only.

The hopper of the work handling equipment holds a three-minute supply of blades to give the operator time to refill it and to remove the hardened blades from the quench tank. The blades are automatically pushed out from the bottom of the stack in the hopper, positioned with the cutting edge in the inductor coil, exposed to a 3.5-second surge of r-f power from a 10-kilowatt Westinghouse generator, and ejected into a basket in the quench tank. A safety device shuts down the generator and work handling equipment if the hopper empties, a blade jams, or the generator becomes overloaded. Frequency of the generator is 450 kilocycles.

Cutting edges of 900 shear blades per hour are hardened with this 10-kilowatt Westinghouse induction-heating generator. After hardening, each blade slides down a chute into the wire basket in the quench tank

Truck-Wheel Balancer

BY S. R. WINTERS
Travelers Rest
South Carolina

A truck or bus wheel with its rubber tire can now be balanced as a unit without removing it from the vehicle by means of a new electronic device.

Basically, the apparatus employs an 8-tube electronic circuit for measuring the amplitude of unbalance vibrations and also to govern the flashing of a stroboscope tube. The functioning of this tube has to be within a tolerance of 0.02 second if the truck or bus wheel is to be properly balanced.

The balancer consists of three units, one of which is a magnetic vibration pickup attached to an accessible part of a truck or bus near the wheel being tested. The second unit is a spinner, capable of accommodating a wheel revolving at a rate of 100 miles or more per hour, which rotates the wheel assembly and rubber tire on the truck or bus axle. The third section is an indicating meter and the stroboscope tube. This section incorporates the electronic circuit which determines the amplitude of the vibrations and controls the flashing of the stroboscope tube.

The axle of a truck or bus is raised from the ground with a conventional jack placed in the center of the axle. Attached to the latter is a magnetic vibration pickup. As the wheel is spun, the meter registers the degree of unbalance to suggest the amount of balancing weights to be applied to the wheel rim. The stroboscope tube is mounted near the revolving rim of the wheel and indicates the spot at which to put equalizing weights. Once the balancing weights have been mounted, the wheel is rechecked readily for equilibrium.

The use of a modified form of the electronic balancer during the war by the U. S. Army Air Forces in testing giant aircraft wheels produced some rather surprising results. In some cases, the instrument detected vibrations having their origin in other sources than unbalance, such as bent axle shafts, loose mountings, bad bearings, bent wheels and poor tires. One spinner took care of a 56-inch wheel on a

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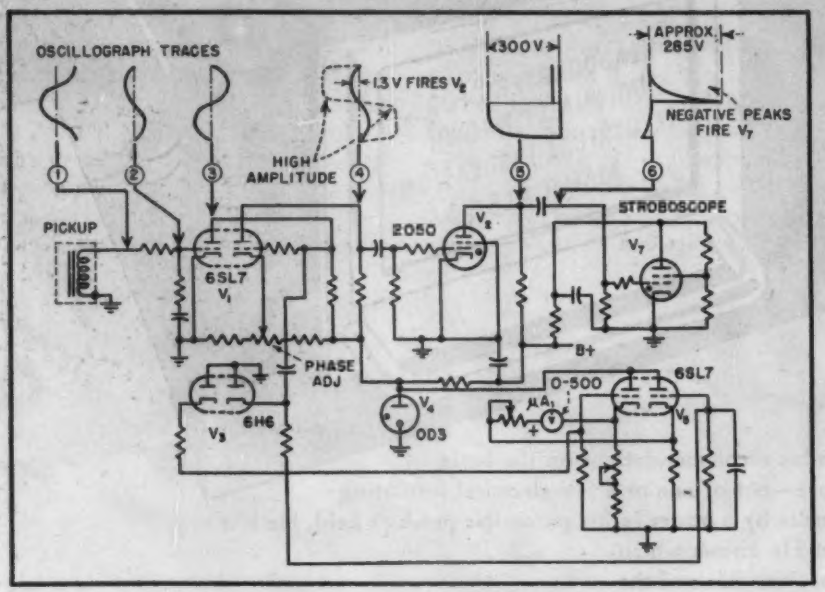
Vibration pickup, wheel spinner, stroboscope lamp and electronic amplifier unit of the truck wheel balancer

B-29 bomber when it was racing up to 117 miles per hour.

The instrument was designed by M. S. Merrill of Denver, Colorado.

The pickup coil of the wheel balancer has a d-c resistance of 2,200 ohms and an output of two volts at 1,200 rpm with an overall amplitude of 0.025 inch



Electronic Timer

BY SYLVAN H. FRASE

Minneapolis, Minn.

CONSIDERABLE experiment with various circuits, both published and original, convinced the writer that timing circuits are by nature obstinate. In the well behaved circuit finally developed, there is no chattering—the timer is inherently stable over any timing range. Long time delays with relatively small capacitance and complete coverage of the timing range with one ordinary volume control are provided.

The circuit of the timer is shown in Fig. 1. This is a backwards relay circuit in which the coil is energized except during the timing interval. Starting with the switch in position 1, the drop across the relay charges C_1 through the surge-limiting resistor R_2.

When the switch is thrown to position 2, C_1 starts to discharge through the 6V6. The gas tetrode is definitely cut off by the high bias from C_1, regardless of the time interval chosen, and it likewise is restored to conductance when the bias voltage has fallen to the value at which the plate takes control. The resulting snap action on both make and break provides accurate timing. Neither the adjustment of the relay nor the load handled by its contacts affects the timing.

The 6V6 acts as a variable resistor that transforms an ordinary 0.5-megohm volume control into a variable resistance of many megohms, making long time delays possible with a small value of C_1. Both grids of the 6V6 are returned to the negative side of R_1 so that the tube resistance is extremely high when R_1 is set at maximum, yet the discharge can never be completely cut off.

Since the 2051 grid is highly negative during the discharge, there is no trouble from grid conduction in that part of the circuit. The circuit values as shown provide a time range from 0.5 to 120 seconds, with a roughly logarithmic calibration, so that exposure ratios and errors of setting tend to be constant over much of the range, depending on the resistance taper

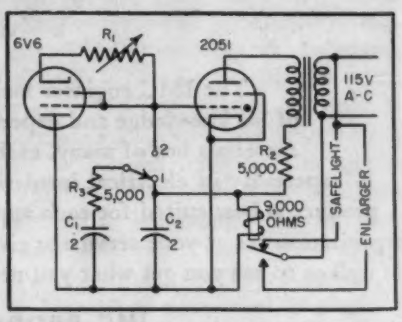
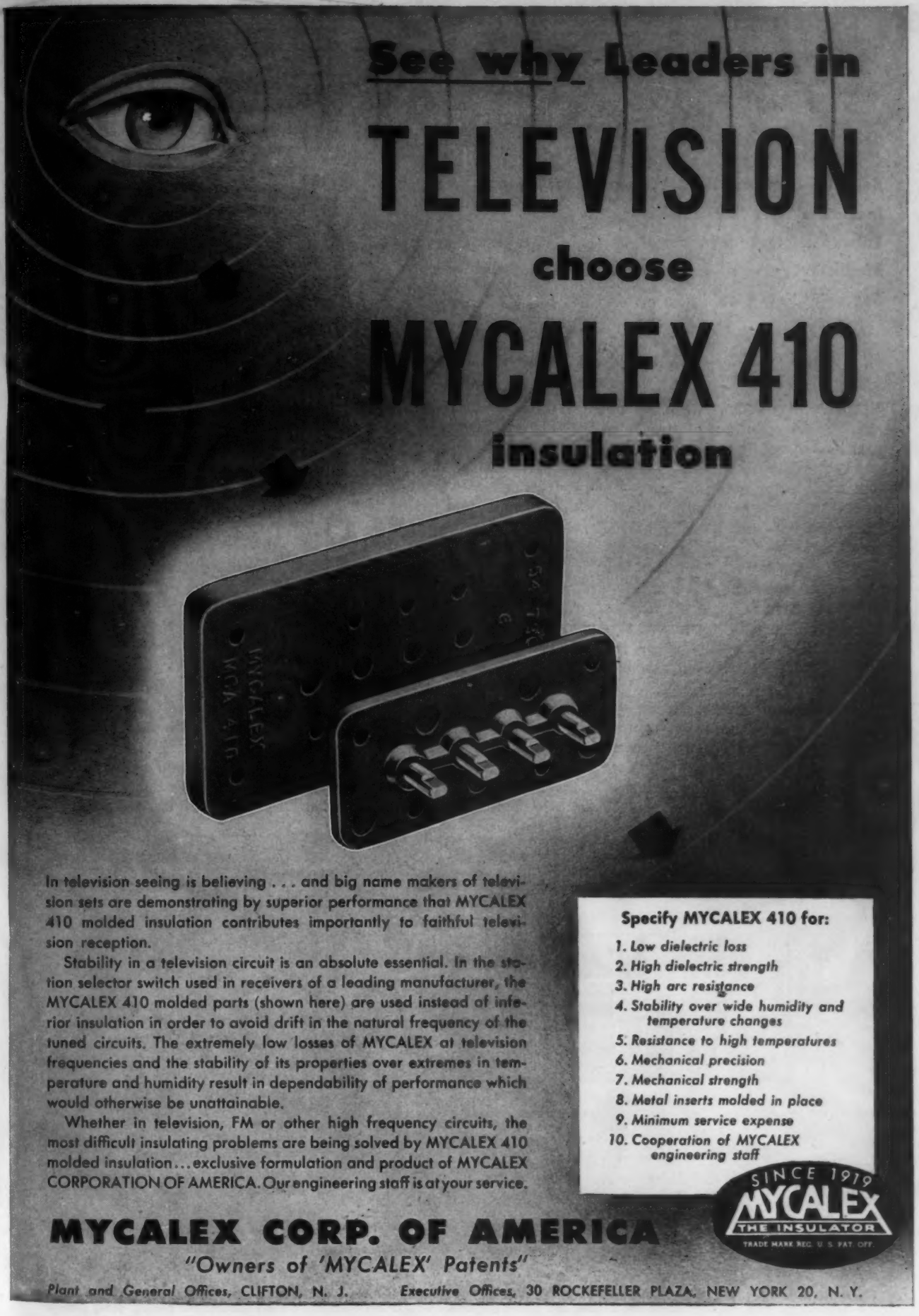


Fig. 1—The relay in the timer circuit is of the type that pulls in at 10 ma and drops out at 6 ma

of the control.

There is some tendency toward self-compensation for line voltage variations. At any rate, deviations from calibration are well within the allowable tolerance for photo-

(continued on p 150)



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3. *High arc resistance*
4. *Stability over wide humidity and temperature changes*
5. *Resistance to high temperatures*
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7. *Mechanical strength*
8. *Metal inserts molded in place*
9. *Minimum service expense*
10. *Cooperation of MYCALEX engineering staff*

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THE ELECTRON ART

Edited by FRANK ROCKETT

Selective Sequence Digital Computer for Science 138
Insulators That Can Amplify 140
Tubes Designed for Industry 172
Magnetic Leakage Evaluated with an Electrolytic Tank 178
Survey of New Techniques 186

Selective Sequence Digital Computer for Science

ELECTRONIC CALCULATORS make possible rapid solution of problems that have heretofore been so laborious that either their solutions have not been attempted or have required much time and effort. Solving problems requiring repeated computations of the same equations but for different sets of values is a matter of routine. Once creative scientists have reduced physical or social problems to formulas, this remaining routine portion of the solutions can be relegated to a machine.

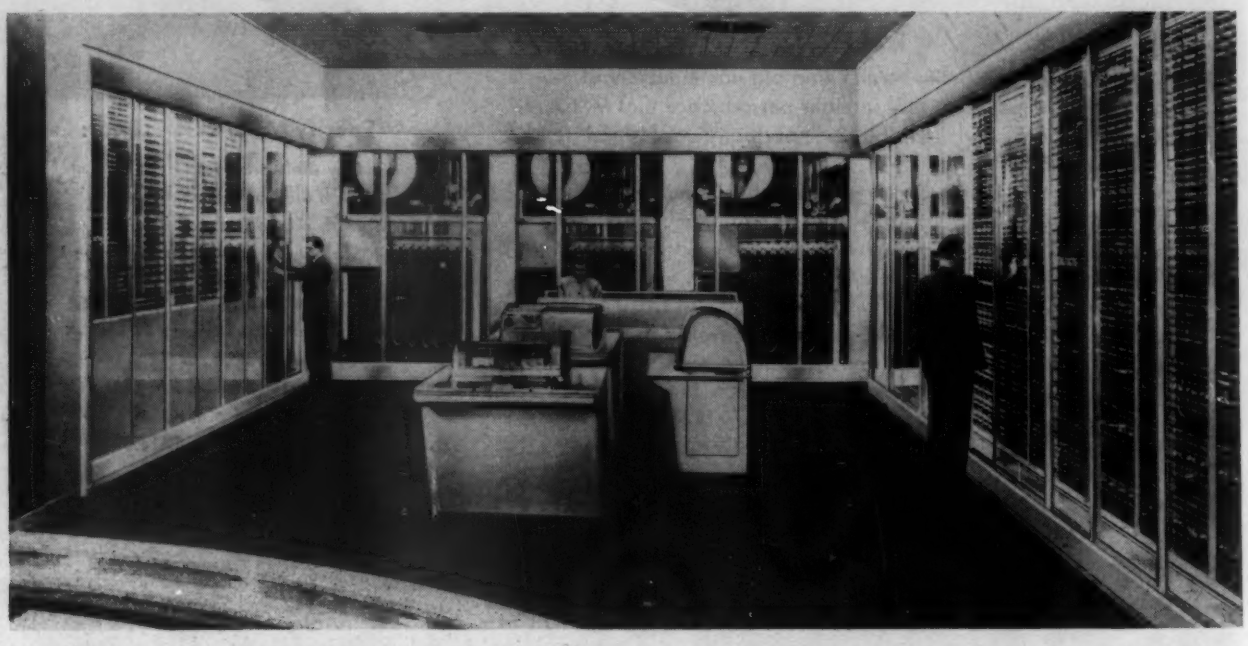
Toward this end of relieving scientists of the mechanics of computation of extensive problems, International Business Machines Corp. has built the Selective Sequence Electronic Calculator. A staff of mathematicians headed by Dr. W. J. Eckert, director of the Watson Scientific Computing Lab., Columbia University, and the machine are being made available to scientists as a computing service.

Calculating Ability

In addition to having the largest memory capacity of any existing calculator, this new machine, designed under F. E. Hamilton's supervision, surpasses its predecessor, the IBM Automatic Sequence Controlled Calculator presented in 1944 to Harvard University, in its ability to program its operations, giving it 250 times that calculator's productive capacity. Gate circuits enable the machine to proceed with other portions of a computation while the main portion is progressing, if the auxiliary manipulations are to be done by unused channels, hence the term "selective sequence."

Both the numbers for calculation and the instructions for operation are supplied to the machine from standard punched cards. These punchings are then transferred to a continuous tape. Reference tables of functions, constants, and other tabular data that the machine will need during the problem are also punched on endless tape loops. Throughout the computer there are 66 tape reading units for various purposes. As computation proceeds, numbers and instructions are transferred from the tape to the bank of 21,400 relays. Final arithmetical operations, which are all reduced to binary additions—subtraction being done by adding complements, multiplication by repetitive additions, and division by repetitive additions of complements—are performed electronically by 12,500 tubes at the rate of 3,500 additions a second of 19 digit numbers.

The memory also uses these four elements. Electronic storage (1) is used for digits that must be reused very shortly. Relays (2) store material that will be recovered as needed. Continuous tapes (3) are punched to store numbers that will not be required until later. These elements have a combined storage of 400,000 digits. By using punched



Electronic calculator, put into operation from punched cards, uses punched tapes for slowly moving computations, relays for faster operations, and vacuum tubes for high-speed manipulations. Computing elements are air-conditioned behind glass panels

FM SIGNAL GENERATOR

Type 202-B 54-216 mc.

Additional coverage from 0.4—25 mc. with accessory UNIVERTER Type 203-B

Shown above is an interior view of the 202-B Signal Generator RF assembly with shield cover removed. Heavy aluminum castings form the mounting base of this RF unit resulting in a compact and highly rigid structure. Girder type condenser frame construction, multiple rotor shaft grounding contacts, and welded interstage shield plates are but a few of the many design features of this unit which give added circuit stability.

Designed to meet the exacting requirements set forth by leading FM and television engineers throughout the country, the 202-B FM Signal Generator has found widespread acceptance as *the* essential laboratory instrument for receiver development and research work.

Frequency coverage from 54 to 216 megacycles is provided in two ranges, 54 to 108 megacycles and 108 to 216 megacycles. A front panel modulation meter having two deviation scales, 0-80 kilocycles and 0-240 kilocycles, permits accurate modulation settings to be made.

Although fundamentally an FM instrument, amplitude modulation from zero to 50%, with meter calibrations at 30% and 50%, has been incorporated. This AM feature offers increased versatility and provides a means by which simultaneous frequency and amplitude modulation may be obtained through the use of an external audio oscillator.

The internal AF oscillator has eight modulation frequencies ranging from 50 cycles to 15 kilocycles, any one of which may be conveniently selected by a rotary type switch for either amplitude or frequency modulation.

The calibrated piston type attenuator has a voltage range of from 0.1 microvolt to 0.2 volt and is standardized by means of a front panel output monitor meter.

The output impedance of the instrument, at the terminals of the R.F. output cable, is 26.5 ohms.

AVAILABLE AS AN ACCESSORY

is the 203-B Univerter, a unity gain frequency converter which, in combination with the 202-B instrument, provides the additional coverage of commonly used intermediate and radio frequencies.

R.F. Range: 0.4 mc. to 25 mc.

R.F. Increment Dial: ±250 kc. in 10 k.c. increments.

R.F. Output: 0.1 microvolt to 0.1 volt. Also approximately 2 volts maximum (uncalibrated).

UNIVERTER
Type 203-B

For further information write for Catalog E

BOONTON RADIO Corporation
BOONTON·N.J.·U.S.A.

DESIGNERS AND MANUFACTURERS OF THE "Q" METER . . . QX-CHECKER . . . FREQUENCY MODULATED SIGNAL GENERATOR . . . BEAT FREQUENCY GENERATOR . . . AND OTHER DIRECT READING TEST INSTRUMENTS

Mathematical operations and calculator performance are monitored or manually controlled from this console

Computational results are printed as obtained, or can be stored on punched cards for later reference

cards (4) as a supplementary storage medium, the memory capacity is made almost limitless. (The count given above for relays and tubes included those used for storage and control as well as for computation.)

Operating Speed

This sequence illustrates the basic philosophy of increasing speed as the complexity of detail increases. High operating speed has been built into the machine on this basis. Cards are punched manually from mathematicians' written notes. This process is necessarily slow, but permits correcting mistakes simply. The information at this level is general, such as "multiply result of previous computation by sine of angle marked in next column." The instructions and numbers, transferred by two card reading units to tape at 30,000 digits a minute, are then passed from tape to calculator at 140,000 digits a minute. The relays, operating at the next greater order of speed, index the tapes carrying trigonometric tables to the proper angle and read off the sine. The relay memory will be storing the results of the last computation. These two banks of relays, one operated by the sine tape, the other acting as a short-time memory, deliver their numbers to the electronic arithmetical units, which are essentially binary counters, where the actual multiplication is done. During the multiplication, intermediate results are stored in the electronic memory.

Programming the calculator is performed by a similar sequence of punchings, relays, and electronic switches. Thus each division of the machine is continuously operating at its full capacity and the solution flows smoothly through the maze of interconnections. Although these connections provide the usual mathematical operations, 40,000 multichannel plug connectors are used so that special functions can be provided if required.

Results are printed either as punched cards at 16,000 digits a minute, or as pages typed at 24,000 digits a minute. An auxiliary unit automatically prints and proofreads results if the results are to be published.

Special Design Problems

The calculator requires 180 kw. Grid-controlled gas-tube electronically regulated power supplies provide the various voltages that are required. For the most part, common supplies are used, decoupling being provided through bypass capacitors at each stage.

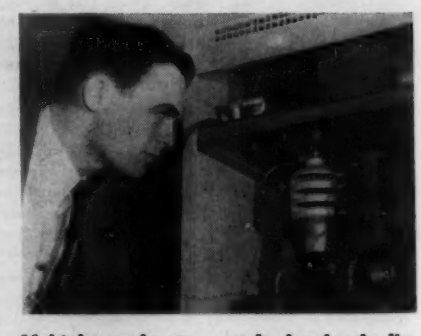
Experience with this calculator has indicated that low-voltage heater tubes are generally more reliable than higher voltage ones. Failure of components including tubes is difficult to anticipate from preliminary tests. In operation, capacitors short, resistors change value and finally open, emission falls in tubes, or they develop opens or shorts. With miniature neon bulbs throughout the computer, it is a simple matter to locate faults and, as everything is directly accessible from the corridors behind the panels, repairs can be made promptly. The simplest method of eliminating faulty components has been to give the computer a run-in of several months. The frequency of interruptions has greatly decreased during this trial period.

Most of the vacuum tubes are operated as on-off switches. Grids are biased well beyond cutoff. The operating cycle consists of an actuating pulse keying the tube on for the appropriate duration, during which digit pulses can trigger the circuit. Even if static tube tests indicate low emission, it has been observed that some tubes will produce strong output pulses. The circuits are directly coupled for d-c response and designed to pass up to 100 kc. A master tunable timing oscillator controls the basic pulse rate, usually set to 50 kc.

Heat developed in the equipment is dissipated by an air-conditioning unit that maintains the incoming air at 50 F and the exhaust at 95 F, and is capable of handling 200 kw. The calculator is divided into three fire zones with automatic temperature detection, alarm and air-conditioning interlocks. In the event of fire, CO_2 would be discharged into the affected zone.

Insulators That Can Amplify

CONTROLLING flow and amplification of electrons by bombarding diamonds (ELECTRONICS, p 144 Dec. 1947) and other insulators is being investigated by Dr. K. G. McKay of

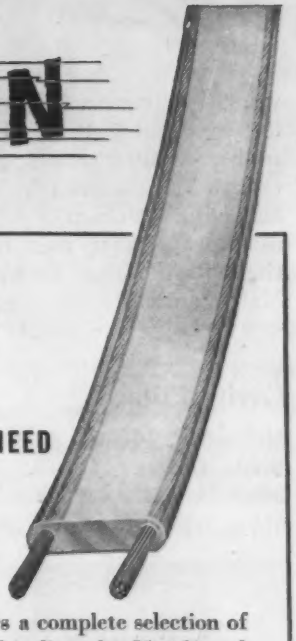


Multiple-accelerator c-r tube bombards diamonds to produce high amplification

Bell Telephone Labs., where the phenomena was discovered. The technique may lead to development of new types of electronic tubes,

(continued on p 172)

How to Smooth ROUGH RECEPTION



ANACONDA Type ATV* Lead-In Lines go a long way towards bringing perfect reception to television and FM sets.

The effects of attenuation and impedance mismatch on reception are minimized by ATV lines. The satin-smooth polyethylene insulation of this line sheds water readily—thus avoiding subsequent impedance discontinuities. This insulating material also has high resistance to deterioration.

Count on Anaconda to solve your high-frequency transmission problems—with anything from a new type lead-in line to the latest development in coaxial cables.

*Reg. U.S. Pat. Off.

A TYPE ATV LEAD-IN FOR EVERY NEED

Anaconda offers a complete selection of Type ATV lead-in lines for 75, 150 and 300 ohms impedance, unshielded and shielded lines of high impedance. For an electrical and physical characteristics bulletin, write to Anaconda Wire and Cable Company.

ANACONDA

Anaconda Wire and Cable Company

25 BROADWAY, NEW YORK 4, N. Y.

NEW PRODUCTS

Edited by A. A. McKENZIE

New equipment, components, tubes, testing apparatus and products closely allied to the electronics field. A review of catalogs, handbooks, technical bulletins and other manufacturers' literature

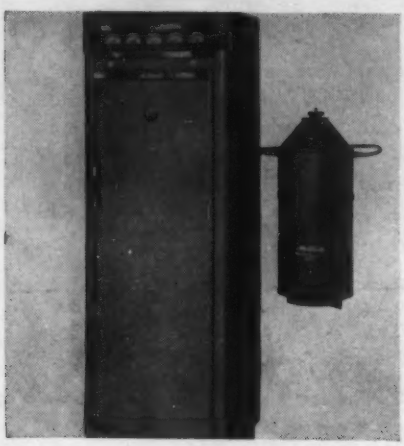
Television Aligner

KAY ELECTRIC CO., Pine Brook, N. J. The Mega-Pipper is a new tele-

vision receiver production and service alignment instrument that gives four crystal-controlled pips to establish the picture, sound carrier, and adjacent channel points on an oscilloscope when used in conjunction with the Mega-Sweep or Mega-Match units.

Cavity Filter

MOTOROLA, INC., 4545 Augusta Blvd., Chicago 51, Ill. A high-Q bandpass filter of the cavity resonator type allows use of a single



antenna for two transmitters separated by one megacycle in frequency. It can also be used to reduce interference from a nearby station in receivers. Particularly designed for the 152-to-162 mc band, its normal insertion loss is 3 db.

Precision Variable Resistors

TECHNOLOGY INSTRUMENT CORP., 1058 Main St., Waltham 54, Mass. Type RV 3–5 potentiometer precision variable resistor has an overall depth of 1⅝ inches and a power

rating of 5 watts. The device is available in nine standard resistance values between 100 and 50,000 ohms. Standard models have an accuracy of plus or minus 5 percent, although an accuracy of plus or minus 1 percent can be supplied. Other features are standard in the line of resistors.

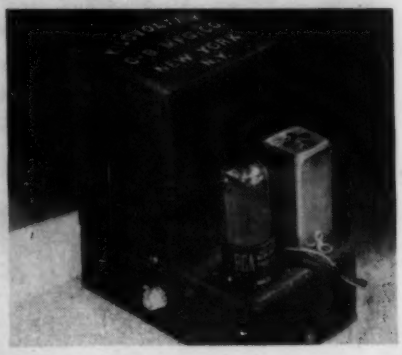
Depth Sounder

TRIDENT PRODUCTS, INC., 110 W. Alameda St., Burbank, Calif., announces a new electronic depth sounder, the DS-2 designed for

commercial craft and moderate-sized yachts. Depths from 0 to 100 fathoms are indicated. It may be operated from 6, 12, 32 or 110 volts d-c, with a 30-watt power drain. Price is $760.

R-F High Voltage

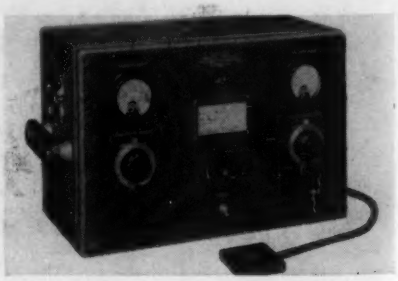
C-B MFG. CO., 412 West 37th St., New York 18, N. Y. The Kilovolter



delivers 600 microamperes at 6,000 volts d-c or 1 milliampere at 4,000 volts. Operating from the B supply of a receiver, the unit operates on the r-f high-voltage principle. It weighs 2 pounds.

Generator for Ultrasonics

TELEVISO PRODUCTS CO., 7466 West Irving Park Road, Chicago 34, Ill. The model U-100 Ultrason ultrasonic generator has a power output of 6 watts in the frequency range



Sounds GOOD to HER

RAYTHEON Subminiature Tube Helps Make This New DICTAPHONE Electronic Transcribing Machine A Model Of Clarity, Tone Quality And Quick Action.

Actual Size — this tiny Raytheon Subminiature Tube Type CK510AX neatly tucked away in the base of this Dictaphone Model "BE" has a lot to do with the efficiency, instant action and compactness of this new electronic office machine.

One of these Raytheon Subminiatures takes the place of *two* old style tubes and its small size results in lower microphonics.

The special design of this tube simplifies filtering of the AC ripple.

Says Dictaphone Corporation

"Because of new electronic devices and skills, developed through war research, it is possible to offer vastly improved over-all reproduction. This model pioneers in the use of subminiature quick-heating tubes. The secretary can now adjust, in all respects, the characteristics of the recorded voice to her ear and to her typing speed in order to insure maximum ease and comfort in transcription."

Why Dictaphone Corporation and many other manufacturers of up-to-the-minute electronic equipment use RAYTHEON Subminiature Tubes.

1. **Increased Product Salability.** Raytheon filamentary Subminiatures are *flat*. Filament drain is extremely low. Product may be smaller and more convenient to use.
2. **Plug Into Standard Sockets.** All Raytheon Subminiatures can either be soldered in or plugged into readily available sockets.
3. **Raytheon Reliability** — the result of unique precision methods and nine years continuous production of long-life Subminiature Tubes.
4. **Readily Available From Stock** — over half a million on tap at all times. Over 30 types. Standard throughout the world.
5. **At Your Local Distributor's** — over three hundred Raytheon Special Purpose Tube Distributors ready to serve you quickly and intelligently.

Write for Data Sheets on
Raytheon Subminiature Tubes

RAYTHEON

Excellence in Electronics

RAYTHEON MANUFACTURING CO.
SPECIAL TUBE SECTION
NEWTON 58, MASSACHUSETTS

Radio Receiving Tubes • Subminiature Tubes • Special Purpose Tubes
Microwave Tubes

from 430 to 470 kc. Model U-300 Ultrason is also described in Bulletin 37 which also gives a history of the subject and an extensive bibliography.

Data Recorder System

COOK RESEARCH LABS., 1457 Diversey Parkway, Chicago 14, Ill. Model CR-6 data recorder system accom-

modates 7 information channels. The separate signals are fed into a magnetic tape recorder and the recording is later played back into a 7-pen graphical device for visual display. Essentially, the equipment takes the place of bulky recording equipment at the point of the test and avoids the necessity for telemetering.

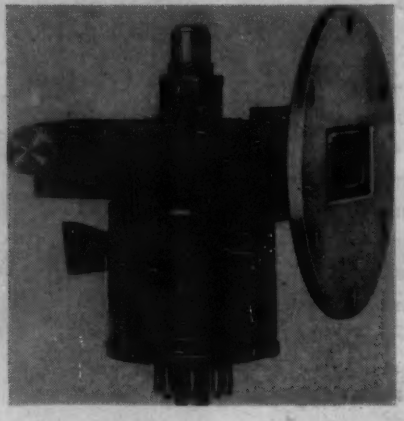
High D-C Supply

CONDENSER PRODUCTS CO., 1375 N. Branch St., Chicago 22, Ill. In production are Hi-Volt PS-1 and

PS-2 power supplies that transform 118 volts a-c to 2,400 volts d-c. This unit is particularly designed for use in electronic photoflash and spectrographic analysis equipment. Model PS-2 is for use in radiation counters, oscilloscopes, and television receivers. A specification sheet can be obtained from manufacturer.

Klystrons

SPERRY GYROSCOPE CO., Great Neck, N. Y. Type SRC-8 high-power reflex klystron illustrated generates microwave energy in the band of



radio frequencies between 6 and 7 kilomegacycles. The SRC-8 series is available in 100 megacycles steps with the exception of a few bench oscillators in 400 megacycle steps.

Ultrasonic Generator

PIEZO PRODUCTS CO., Whitney St., Framingham, Mass. Model A-500 ultrasonic generator has a frequency range of 100 to 30,000 kc at a maximum power output of 400 watts and is furnished with three quartz crystal transducers, crystal holder, and oil immersion tank. Model B-500 is similar in design but equipped for aqueous immersion. Details of equipment and ultrasonic engineering service are available.

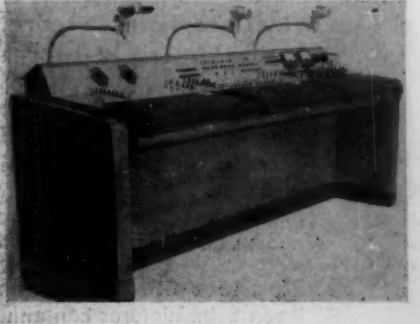
Measuring Equipment

WESTERN ELECTRIC CO., 195 Broadway, New York 7, N. Y., announces

a measuring unit made up of the RA-1258 signal generator and the RA-1257 intermodulation analyzer. Signals of two frequencies are added in the signal generator, passed through the device under test, and fed to the analyzer where the percent intermodulation is read on an electronic voltmeter.

Program Console

GENERAL ELECTRIC CO., Syracuse 1, N. Y. Type TC-6-A program console described in specification RA-14111 has a desk-like three-section



construction for program director, video operator, and audio operator. This position provides a means of coordinating all personnel activities in a television program.

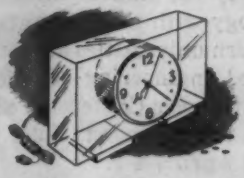
Voice-Activated Recorder

AMPLIFIER CORP. OF AMERICA, 398 Broadway, New York 13, N. Y. Available as optional equipment on any Magnetape recorder is a voice-actuated instantaneous start-stop

(continued on page 198)

Coils that Keep Perfect Time

help a clock company to save production time



On each of these No. 102 Universal Coil Winding Machines, winding of non-insulated coils is so scheduled that manual operations are being performed on one head while the other heads are *producing.*

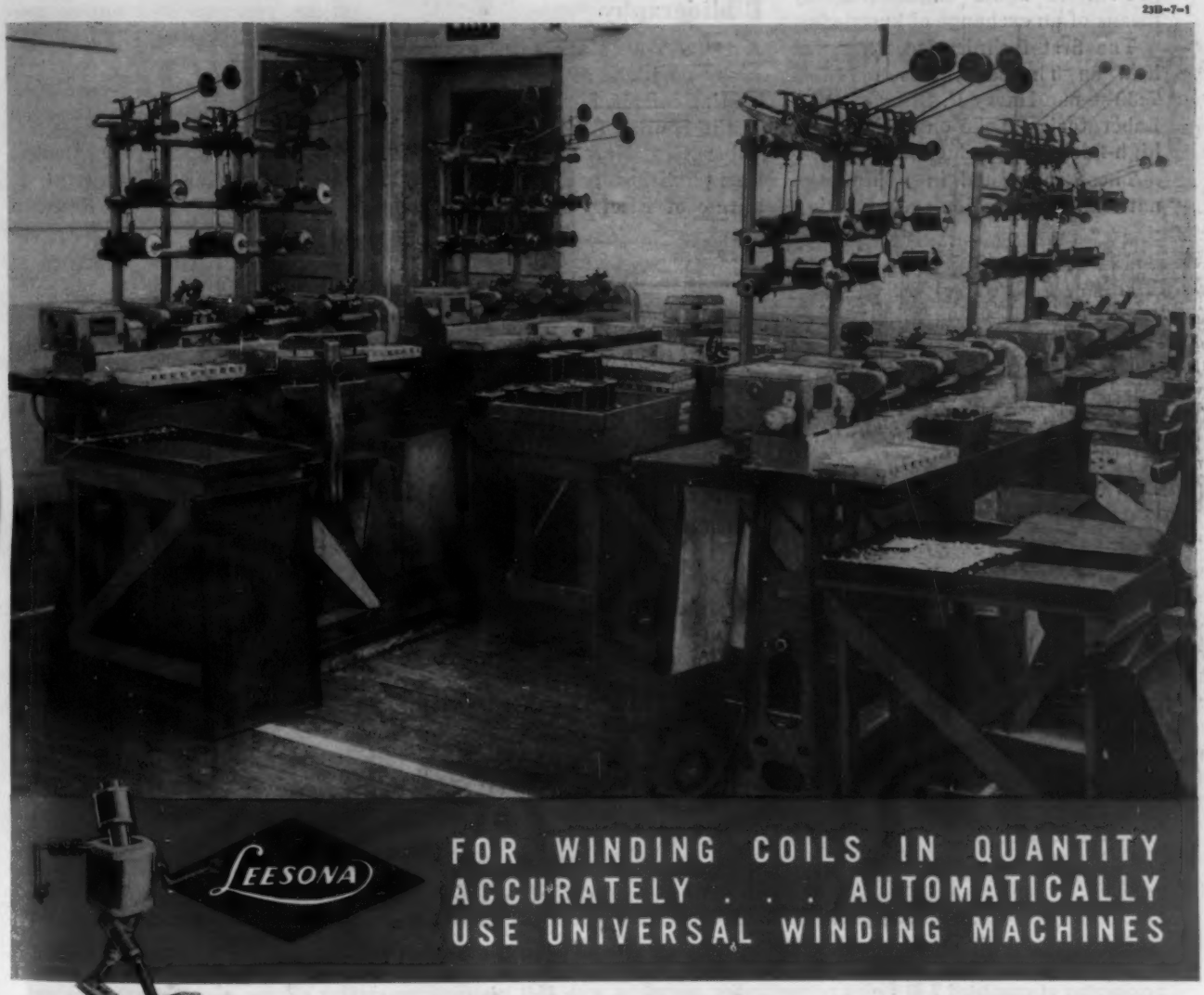
Each machine has three or six individually operated heads, and coil output is synchronized on the basis of handling time per coil. No heads standing idle . . . no waste production time for the operator.

Other time-savers:

1. Electrically-controlled counter stops each head upon completion of coil—no operator attention needed.
2. Common setting for all heads in respect to wire traverse length and number of wire turns per layer.
3. Traverse length and wire turns readily adjustable within maximum range—without changing cams.
4. Steel-strap control on unrolling tensions facilitates handling of even finest wires.
5. In-built calibration for recording settings for reuse.
6. Quick-acting release on supply spindles.
7. 500 to 2500 R.P.M.

Write for Bulletin 102L. Universal Winding Company, P. O. Box 1605, Providence 1, R. I.

23B-7-1



NEWS OF THE INDUSTRY

Edited by JOHN MARKUS

FCC announcements on wired wireless, terrain proximity indicators, and heating frequencies; 12 new books out

Audio Engineering Society Formed

AT a meeting held in the RCA Victor recording studios in New York Feb. 17, the Audio Engineering Society was organized. The session opened with a brief talk by acting chairman C. J. LeBel, consultant. Norman C. Pickering then discussed the need for a professional organization to foster the growth of audio engineering by means of an exchange of knowledge.

The first technical meeting was held on Thursday, March 11, at 7:30 p. m. Harry F. Olson of RCA Laboratories spoke on problems of high-fidelity reproduction.

Those interested in joining the national organization or in forming local sections should write the acting secretary, Norman C. Pickering of Pickering and Co., Inc., Oceanside, N. Y., giving name, mailing address, company affiliation and nature of work.

Dielectric Heating Bibliography

A TWENTY-PAGE annotated bibliography on high-frequency dielectric heating compiled by Ralph A. Rusca of the Southern Regional Research Laboratory, New Orleans, La., has been published by the American Institute of Electrical Engineers, 33 W. 39th St., New York 18, N. Y. It contains 231 domestic and 62 foreign references, a section on domestic and foreign patents, and an author index. Regular price is 75 cents; to AIEE members, 35 cents per copy.

Midwest Power Conference

SPONSORED by the Illinois Institute of Technology with the cooperation of midwestern universities and local and national engineering societies, the Midwest Power Conference will be held at the Sheraton Hotel in Chicago on April 7-8-9.

Two sessions of interest to electronic engineers on Friday April 9 are:

10:30 a.m.—Power and Control. Chairman: A. H. Wing, Chairman of the Electronics Group, Chicago Section, AIEE.

Circuit Principles of Industrial Electronic Control, by Walter Richter of Allis-Chalmers Manufacturing Co., Milwaukee.

Rectifier Power Supplies from D-C Systems, by C. R. Marcum of Westinghouse Electric Corp., East Pittsburgh.

Electronically Controlled Variable-Speed Drives, by Marvin M. Morack of G. E.

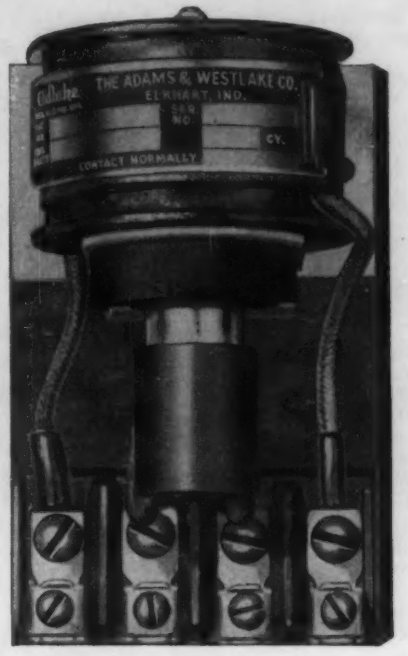
2:00 p.m.—Supervisory Control and Telemetering. Chairman: E. H. Schulz of the Armour Research

Flying Antennas For Television

Retransmission of television and f-m from high altitudes will soon be tested in a modified B-29 equipped with receivers and transmitters. If successful, this stratovision system will provide greater coverage than is possible from a ground antenna. At left is artist's conception of completed B-29 during rebroadcasting operations, with 25-ft telescopic transmitting antenna mast beneath nose and receiving antenna on tail fin. At right, receiver mast is being installed on fin

When you want

SENSITIVITY



use the new

ADLAKE

No. 1045 RELAY

For *reliable* circuit control—when sensitive action is at a premium, you can depend on the new Adlake #1045 (Quick-Acting) Relay.

Along with sensitivity and quick action, #1045 gives you the other advantages that make Adlake Relays ideal in hundreds of convenient applications:

- Hermetically sealed (dust, dirt, moisture, oxidation and temperature changes can't interfere with operation)
- Compression-type terminals simplify installation
- silent and chatterless
- requires no maintenance
- absolutely safe
- cushioned against impact and vibration

USES:

- temperature regulation
- precision instrument control
- photoelectric apparatus
- signals and indicators
- refrigeration control

—and a host of others

The #1045 Relay is especially designed for use with sensitive thermo regulators.

For *any* type of job, specify Adlake Relays—you can always depend on them. For full details write today to: Adams & Westlake Company, 1107 N. Michigan, Elkhart, Indiana. No obligation, of course!

Adlake TRADE MARK

THE Adams & Westlake COMPANY

Established 1857 • ELKHART, INDIANA • New York • Chicago

Manufacturers of Hermetically Sealed Mercury Relays for Timing, Load and Control Circuits

Radio Parts Show Sellout

Indicating that all exhibit booths for the Chicago Parts Show, May 11-14, have been allotted, Charles Golenpaul, president (right) and Kenneth C. Prince, manager, hang out SRO sign

MEETINGS

MARCH 22-25: IRE Convention and Radio Engineering Show, Hotel Commodore and Grand Central Palace, New York City.

MARCH 29-30: AIEE conference on electron tubes for instrumentation and industry. Benjamin Franklin Hotel, Philadelphia, Pa.

APRIL 1-3: AIEE Great Lakes District Meeting, Des Moines, Iowa.

APRIL 7-9: Midwest Power Conference, Sheraton Hotel, Chicago, Illinois. Three papers on supervisory control and telemetering at 2 p.m. April 9.

APRIL 17: IRE Engineering Conference, Chicago Section, Illinois Institute of Technology, Chicago.

APRIL 24: Spring Technical Conference of IRE Cincinnati Section, featuring television papers, at Engineering Society Headquarters.

APRIL 26-28: IRE-RMA spring meeting on transmitters, Syracuse Hotel, Syracuse, N. Y.

APRIL 28-30: AIEE North Eastern District Meeting, New Haven, Conn.

MAY 3-5: URSI-IRE joint meeting, Washington, D. C.

MAY 9-14: 1948 Radio Parts Show, Hotel Stevens, Chicago.

MAY 11-16: Engineering Progress Show, Franklin Institute, Philadelphia, Pa.: exhibits and two evening lectures.

MAY 22: Second New England Radio Engineering Meeting, sponsored by North Atlantic Region of IRE, at Hotel Continental, Cambridge, Mass.

JUNE 21-25: 51st annual meeting of the American Society for Testing Materials, at Detroit, Michigan.

JUNE 21-25: AIEE Summer General Meeting, Mexico City, Mexico.

AUG. 24-27: AIEE Pacific General Meeting, Spokane, Wash.

SEPT. 13-17: Third Instrument Conference and Exhibit, Convention Hall, Philadelphia, Pa.

SEPT. 27-Oct. 2: Third National Plastic Exposition, Grand Central Palace, New York City.

SEPT. 30-OCT. 2: Pacific Electronic Exhibition and IRE west coast Annual Convention, Biltmore Hotel, Los Angeles, Calif.

OCT. 5-7: AIEE Middle Eastern District Meeting, Washington, D. C.

OCT. 11-12: FM Association Second Annual Convention, Sheraton Hotel, Chicago.

Foundation of Illinois Institute of Technology.

Telemetering of Power, Reactive Power, and Similar Quantities, by Nathan Cohn of Leeds and Northrup Co., Chicago.

Telemetering Channels, by R. J. Donaldson of Commonwealth Edison Co., Chicago.

Supervisory Control, by A. P. Peterson, president of Control Corporation, Minneapolis.

Wired Wireless Rules

PRESENT FCC rules on such low-power apparatus as phono oscillators, wired wireless, and broadcast carrier-current equipment are under consideration for revision. Since adoption of these rules in 1938, stipulating essentially that the r-f electromagnetic field shall not exceed 15 μv per meter at a distance in feet equal to 157,000÷frequency in kc, the r-f spectrum has become still more congested. To keep essential radio services free from objectionable interference, operators and manufacturers of devices intended to come within existing low-power rules have been warned to comply with existing regulations and to expect considerably more stringent regulations soon.

Terrain Proximity Indicators

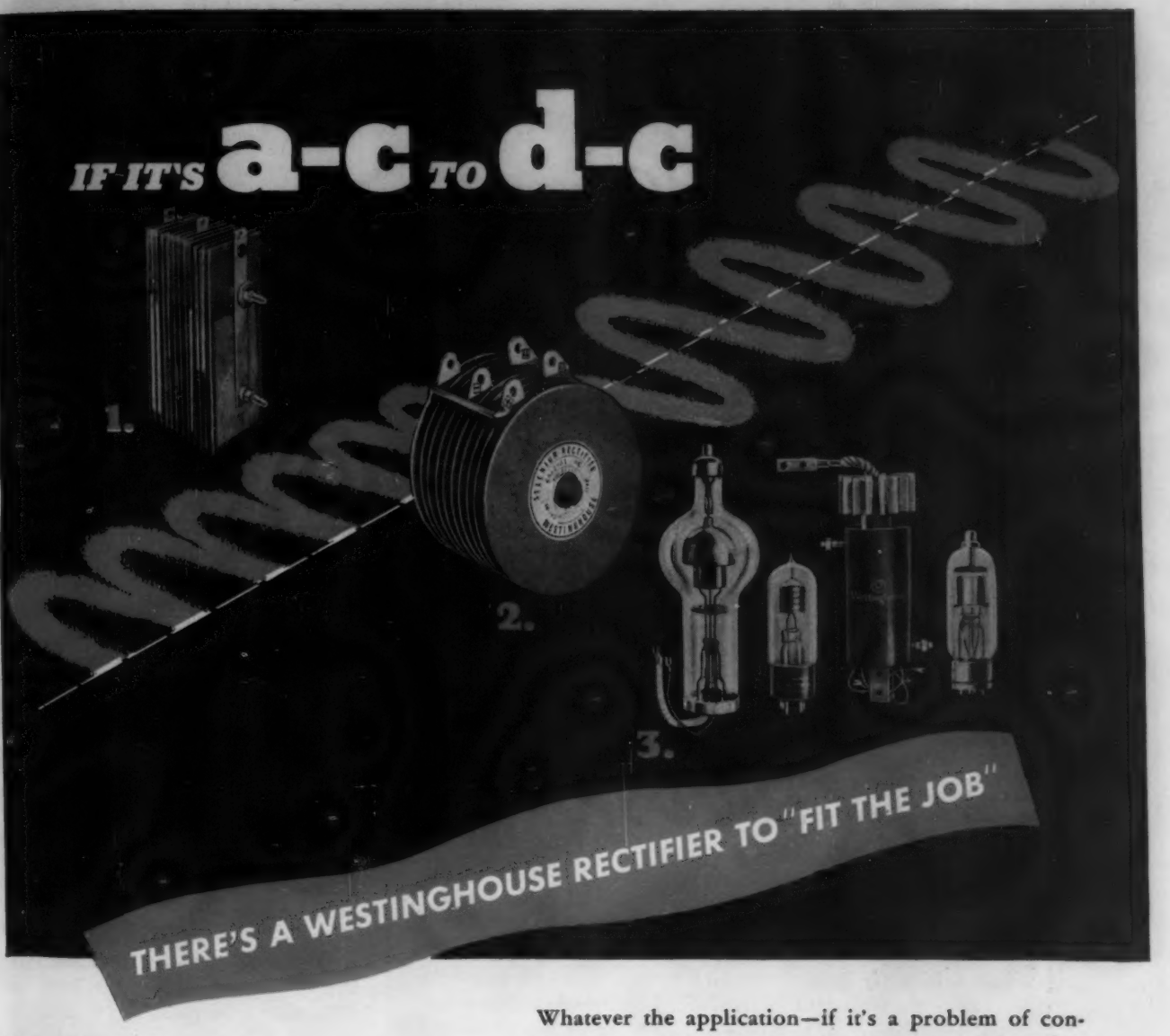
TEMPORARY authorization for the 420- to 460-mc band was given to aeronautical navigational altimeters by the Federal Communications

((continued on page 236)

RECORDING FOR HOME FOLKS

Sound recording room in House office building, one of five such studios available to lawmakers for objective speeches. About 175 senators and congressmen make weekly recordings

Senators record a round table discussion in Washington studio for broadcast over radio stations in their home districts. Lawmakers pay $3 for each 15-minute transcription



1. **RECTOX** . . . for dependability and long life. Original Rectox Copper-Oxide units installed 20 years ago are still in use today . . . a service record not duplicated by any other metallic rectifier.

2. **SELENIUM** . . . providing a dependable, economical source of d-c power where small size and minimum weight are prime factors. Westinghouse Selenium Rectifiers are the result of more than nine years of continuous research.

3. **ELECTRONIC TUBES** . . . Westinghouse Phanotron, Thyratron, Kenotron, Ignitron and other types of tubes meet the requirements of such varied applications as radio transmitters, speed controls, resistance welding control and x-ray equipment.

Whatever the application—if it's a problem of converting a-c to d-c—there's a Westinghouse Rectifier to do the job. And whatever the problem, Westinghouse engineers, with a background of more than 20 years in the development and application of rectifiers, can offer you the best possible solution.

Manufacturing limitations can be met—maintenance problems avoided—control problems simplified—with the Westinghouse complete range of *all* types of rectifiers from which to select. Take advantage of this broad background of help on your rectifier problems—outline your requirements to your Westinghouse representative or write for further information—Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa. J-21421

Westinghouse *Rectifiers*

PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

Out of the deepest silence...

...comes the finest in sound

THE 757A LOUDSPEAKER

Here at Bell Telephone Laboratories, in one of the most completely noise-deadened rooms in the world, the microphone hears . . . and passes on to delicate frequency-response recorders . . . no sound except the voice of the Western Electric *757A Loudspeaker*. A two-foot masonry shell shuts out all external noise. Walls of wedge-shaped cages—glass-wool-filled—absorb sound completely. A "floor" of steel strands reflects no sound.

The recorded frequency-response charts confirm the evidence of all other tests—that the 757A attains the *finest in sound!*

Highest quality, high efficiency, frequency response from 60 to 15,000 cycles, 30-watt power capacity . . . the 757A's unique combination of these features is matched by *no other speaker* on the market. The 757A more than meets the requirements of even the finest audio system for broadcasting and sound distribution.

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(continued from p 136)

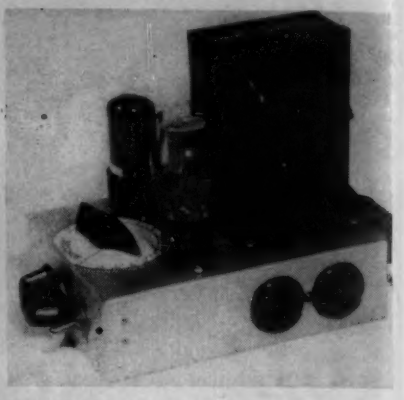


FIG. 2—Time intervals from 0.5 to 120 seconds are provided by this timer

graphic work. In the model constructed, they have been almost undetectable.

The transformer in the complete unit shown in Fig. 2 is huskier than necessary. It need deliver only about 20 milliamperes at about 250 volts, plus filament current. The current-limiting resistor R_3 could be dispensed with if a lower voltage transformer were used. However, the additional voltage drop across this resistor would be useful for increasing the time delay if desired.

The double outlet shown in the photograph has a split bus so that a dark-room safelight can be turned on by the relay between exposures. A self-starting electric clock with a sweep second hand, plugged into the enlarger outlet, is helpful in the calibration process.

Construction of Shielded Room in VHF Field

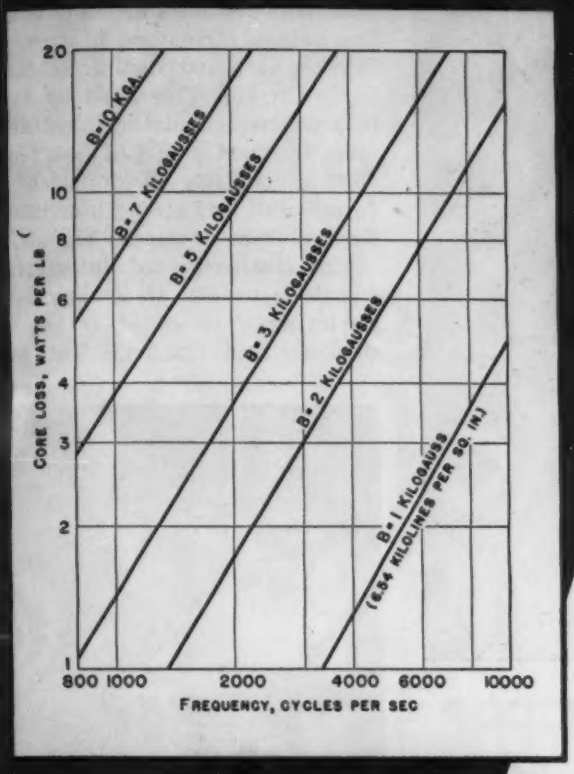
By CECIL C. PINE

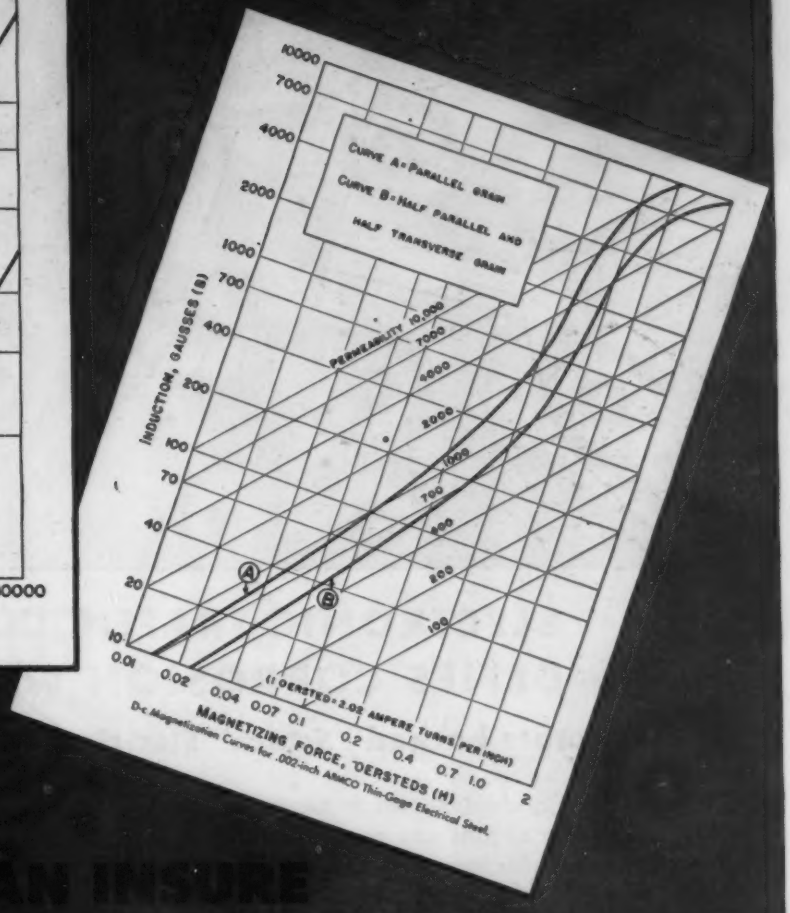
Sperry Gyroscope Company
Great Neck, New York

PRESENT-DAY development of vhf and uhf equipment necessitates the modernizing of the conventional screened room. In fact, an ordinary double or triple shielded room utilizing copper or galvanized iron mesh is ineffectual when subject to interference such as that caused by uhf radiations of extremely high peak power.

The shielded room to be described was the outgrowth of an effort to provide a means for testing radio direction-finding equipment under conditions of very severe local disturbances, and to date it has proved adequate in all respects.

The first requirement in aligning


CORE LOSS, WATTS PER LB
FREQUENCY, CYCLES PER SEC
B = 10 KGA.
B = 7 KILOGAUSSES
B = 5 KILOGAUSSES
B = 3 KILOGAUSSES
B = 2 KILOGAUSSES
B = 1 KILOGAUSS
(6.54 KILOLINES PER SQ. IN.)


CURVE A = PARALLEL GRAIN
CURVE B = HALF PARALLEL AND HALF TRANSVERSE GRAIN
INDUCTION, GAUSSES (B)
PERMEABILITY
MAGNETIZING FORCE, OERSTEDS (H)
(1 OERSTED = 2.02 AMPERE TURNS PER INCH)
D-c Magnetization Curves for .002-inch Armco Thin-Gage Electrical Steel.

NOW YOU CAN INSURE low energy loss at high frequencies

ARMCO Thin-Gage Electric Steel—a war-born development of ARMCO Research—is making its mark in the development of magnetic cores for television, radar, sonic detection, and many other high-frequency devices.

Whenever applications involve changes in magnetic flux equivalent to frequencies from 400 to as high as 1,000,000 cycles per second, this steel has five definite advantages:

1. Supplied in coils suitable for high-speed punching operations or for winding into cores.

2. Skin-effect does not become appreciable at high frequencies because thicknesses as light as 1 or 2 mils are obtainable.

3. Considering the gage and insulation on both sides, the stacking factor is high. Four hundred sheets of .002-inch insulated steel make a stack only 1 inch high.

4. CARLITE Insulation, formed by a new surface treatment developed by Armco, effectively insulates each lamination and assures minimum interlamination loss.

5. Hysteresis is unusually low for such thin steel.

Write us for further information pertaining to your specific products. Just address The American Rolling Mill Company, 208 Curtis Street, Middletown, Ohio.

EXPORT: THE ARMCO INTERNATIONAL CORPORATION

ARMCO

ARMCO ELECTRICAL STEELS

ELECTRONIC TRAFFIC COP DEFIES CORROSION with

acetate backed "Scotch" Electrical Tape

Electrolytic Condensers which regulate the flow of current through electronic circuits are comparable to traffic police; they prevent current traffic jams and tie-ups. The more thoroughly these condensers are protected against electrolytic corrosion, the less danger there is of operational interruptions. "SCOTCH" Acetate Film Tape No. 6 is highly corrosion resistant. That is why it is used so successfully to hold the layers of aluminum foil and tissue in a tight roll prior to impregnation. "SCOTCH" Acetate Film Cloth Tape No. 9, extremely high in corrosion resistance, is in use in thousands of electrolytic condensers as a protective wrap around the condenser at the terminal connections to provide insulation. It pays off in the practical elimination of electrolytic corrosion, greatly increased service life, and the reduction of service interruptions in radio, television, and other electronic circuits.

If you have an insulation or electrolytic corrosion problem, remember, there are forty different constructions in the "SCOTCH" Electrical Tape line; among them is sure to be the answer to whatever insulation problem may be bothering you.

Write today outlining your problem; our Technical Service Department will tackle it at once and go all-out to serve you.

REG. U.S. PAT. OFF.

SCOTCH BRAND Electrical TAPE

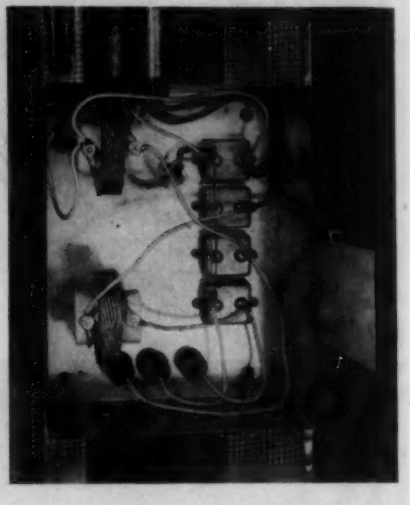
ACETATE FIBER AND ACETATE FILM CLOTH BACKING

ANOTHER 3M PRODUCT

Made in U.S.A. by MINNESOTA MINING & MFG. CO. St. Paul 6, Minn.

and testing automatic d-f equipment is to provide a means of coupling a signal of known field strength into the loop and vertical antenna input circuits. This must be done in a manner simulating ideal field conditions and should be free from all uncontrollable factors such as variation of field strength or interference from unwanted signals.

The elimination of interfering signals is usually accomplished by employing a combined system of shielding and filtering. The test

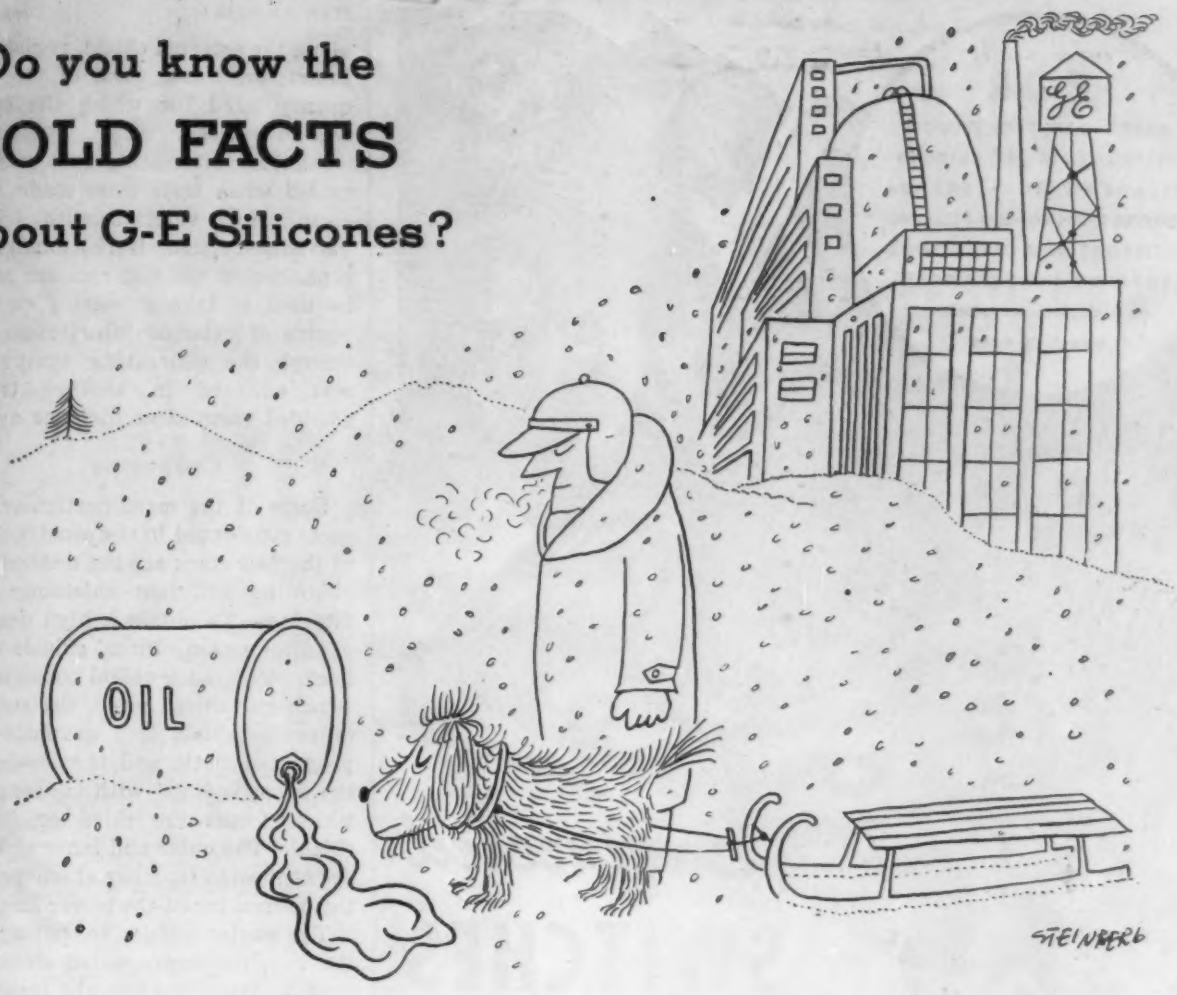


Filter box located on the outside wall of the shielded room. The three microwave filters are insulated from the box by tubing

room is generally constructed with either two or three shields consisting of wire mesh or copper foil spaced from two to four inches apart and connected together at but one point. This technique normally attenuates any radiation exterior to the room from 60 to 100 db. However, any r-f voltage superimposed on the power lines leading into the room will be radiated inside the room and cause trouble. An r-f filter consisting of chokes and capacitors interposed between the power line and the load is generally considered an adequate means of eliminating interference from this source.

An ordinary pi network consisting of two 0.5 μf and two r-f line chokes placed in the power lines leading into the screened room was of little value when the lines exterior to the room were subject to bombardment from a pulsed uhf source. A test receiver connected to the bench conduit, and even to points

Do you know the COLD FACTS about G-E Silicones?



Ever hear of an oil that will still pour even when the temperature drops to —120 F? At General Electric we're manufacturing such an oil. It is known as G-E silicone oil and it has some mighty interesting uses.

For example, manufacturers of stratoliners—high-altitude transports that speed through the extremely cold upper levels of air—will find General Electric silicone oil to be excellent for use in hydraulic systems. With silicone oil acting as the hydraulic fluid, plane builders can guard against the danger of "frozen" landing gear and wing flaps, despite subzero temperatures.

If you're interested in a gasket material which is remarkably resistant to extreme cold, we suggest you investigate General Electric silicone rubber. This unusual material retains its stability and elasticity at a thermometer reading as low as —70 F.

In addition to their resistance to extremely low temperatures, silicone oil and silicone rubber defy very high heat. Silicone rubber remains unchanged at 520 F; silicone oil won't ignite at 575 F.

Another product of G-E silicone research has most unusual moisture-repellent properties. This is G-E DRI-FILM* water-repellent material. It is finding interesting uses in treating textiles, glass, ceramics, plastics, and paper.

WANT TO KNOW MORE ABOUT G-E SILICONES? There's more to know and there are many more uses for these amazing products. Why not drop us a line. Let us discuss your particular production problem with you. *Chemical Department, General Electric Company, Pittsfield, Massachusetts.*

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along the internal shield, registered interference over most of the frequency band for which the room was to be used.

Another interesting fact was revealed when tests were made in a room triply shielded with ¼-inch galvanized mesh. Here a small loop connected to the test receiver could be used to take a bearing on the source of external interference although the generating equipment was enclosed in another triple shielded room some distance away.

Construction

Some of the more particular aspects considered in the construction of the new room are the methods of obtaining sufficient shielding and filtering. To obtain a high degree of attenuation, three shields are used. The outer shield consists of ¼-inch galvanized mesh, the second or center shield is a graphite-impregnated cloth, and the inside of the room is lined with copper foil which forms the third or inner shield. The outer and inner shields are connected together at one point, the neutral leg of the power line.

The center shield, consisting of the graphite-impregnated cloth, is used to attenuate the uhf leakage. This material is extensively used for its ability to absorb any high frequency energy that terminates

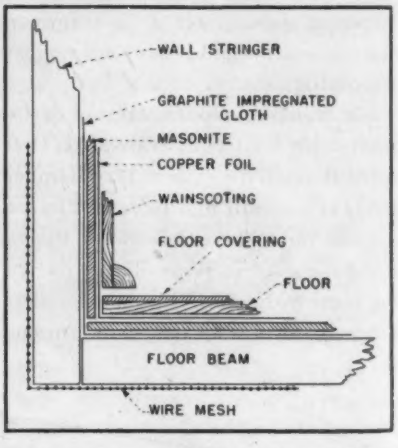

FIG. 1—An expanded view of a portion of the shielded room showing constructional details

upon it, and is here used as a floating shield which merely acts to dissipate the currents flowing in it rather than conducting them to a common ground point as is the case with the other two shields. Fig. 1 gives a general illustration of the

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The TYPE S12-A OSCILLOGRAPH is a complete instrument with internal governor motor, gear-driven record, timing device, record numbering, automatic record-length control, and record footage indicator. Rigid cast aluminum case has carrying strap, measures only ten inches wide by 18 inches long, and weighs only 35 pounds.

Fully described in Technical Bulletin SP-167 A

The TYPE OA-2 GALVANOMETER can be supplied in 66 different combinations of sensitivity and natural frequency, for accurate recording up to 6000 cycles per second. The OA-2 is the only galvanometer suitable for use under extreme vibration or acceleration.

Fully described in Technical Bulletin SP-156 A

The TYPE MRC-12 STRAIN GAGE CONTROL UNIT is the smallest complete six-channel static-dynamic strain gage amplifier and balancing unit in existence. Complete with carrying strap, batteries, six amplifiers, six balancing boxes, and 2000-cycle oscillator, the MRC-12 weighs only 42 pounds.

Fully described in Technical Bulletin SP-177 A

Hathaway
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construction carried on throughout the room.

The framework of the room is constructed of well-seasoned 2 by 3-inch members, the exterior of which is covered with the galvanized mesh. The impregnated cloth is glued to the back of tempered masonite sheets which in turn are nailed to the inside of the framework to form the walls, floor and ceiling. The joints in the cloth backing are overlapped to form a continuous shield, and all nails used in securing the masonite are countersunk.

Copper foil is cemented to the masonite with a heavy Bostick cement. All panelling, light fixtures, and other supported items are held in place by small angle strips which are soldered directly to the copper foil.

Inasmuch as the shielding must be continuous throughout the entire surface of the room, the door is constructed in a similar manner and is provided with special metal stripping which assures a good bond to the respective shields. Ventilating holes cut through the copper and cloth shields are covered with fine copper mesh.

Filtering

A special microwave line filter is used, in conjunction with the more conventional types, to obtain a high degree of attenuation over the entire r-f spectrum. Figure 2 shows the circuit arrangement.

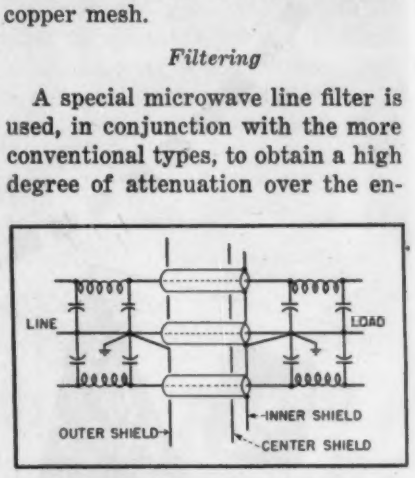

FIG. 2—Schematic diagram of all-wave filter system. The cylindrical forms in the center represent the microwave filters

The first filter section consists of a pi network utilizing 0.5-μf oil-filled capacitors and low-frequency chokes and is installed in a copper-clad box mounted on the outside of the room. The second section makes use of the microwave filters, which are placed in each leg of the power line (including the neutral

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For the Bell System's construction program, Western Electric is producing thousands of miles of coaxial cable, much of it using insulation discs of Du Pont polythene in the coaxial units—as many as 506,000 discs per mile in a typical cable.

The excellent electrical properties of Du Pont polythene which make it adaptable to this type of insulation are these: polythene has a low dielectric constant (2.3). Its low power factor makes it a superior insulator—reduces shunt losses to about 1/12 those present with materials formerly used. In addition polythene has excellent strength and resistance to aging. From the manufacturer's viewpoint, it's modest in cost, easy to fabricate, and is flexible enough to permit quick assembly on the inner wire.

Whenever *your* problem is wire and cable insulation, *look first* for your answer at the properties of Du Pont POLYTHENE. Write us *now* for more information. Have it in your files for quick reference. E. I. du Pont de Nemours & Co. (Inc.), Plastics Department, Room 144, Arlington, N. J.

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Discs measuring approximately $\frac{3}{8}$" O.D. are punched from sheet polythene. Centers are also punched to fit center conductor.

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Discs are mounted on copper inner conductor wire. Polythene permits easy installation, yet doesn't buckle under stress.

Outer conductor of copper tape is formed into tube around inner conductor and bound with steel tape, forming completed coaxial unit.

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Plastics

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Hathaway
INSTRUMENT COMPANY
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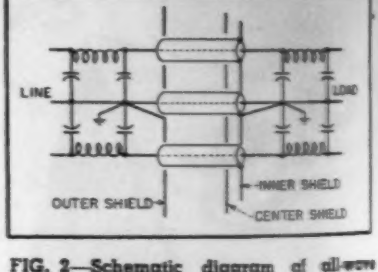

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The first filter section consists of a pi network utilizing 0.5-μf oil-filled capacitors and low-frequency chokes and is installed in a copper-clad box mounted on the wall of the room. The second filter makes use of the metal conduits which are placed in the power line

leg). These filters form the connecting means from the outer box to the interior of the room. Inside the room is another copper-clad box, in which is located a third filter section consisting of 0.5-μf oil-filled capacitors and high-frequency chokes.

As shown in Fig. 2, the outer and inner shields are connected together by means of the neutral wire through one of the microwave chokes. A more detailed illustration of the microwave choke is given in Fig. 3.

A test receiver placed in a room of the type described was unable to

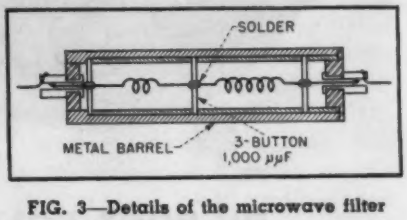

FIG. 3—Details of the microwave filter

detect any type of interference over the entire band from 200 to 1,600 kilocycles; although, by opening the door by as much as one-eighth

TIME as a factor of CONTROL in Industry

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The excellent electrical properties of Du Pont polythene which make it adaptable to this type of insulation are these: polythene has a low dielectric constant (2.3). Its low power factor makes it a superior insulator—reduces shunt losses to about 1/12 those present with materials formerly used. In addition polythene has excellent strength and resistance to aging. From the manufacturer's viewpoint, it's mode[illegible]t, easy to fabricate, and is flexible enou[illegible]mit quick assembly on the inner wire.

[illegible]em is wire and cable insula-
[illegible]nswer at the properties of
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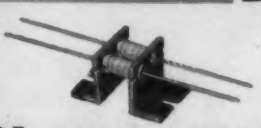
1N39 Designed for exceptionally high back voltages. Ideally suited for use in switching, waveshaping, coupling and clamping circuits involving negative voltages as high as 200. Mechanically identical to 1N34 and 1N38.

DUO-DIODES *and* VARISTORS



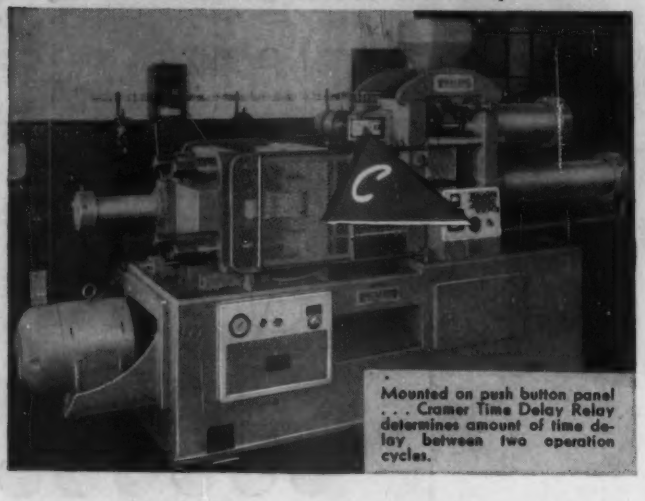
1N35 A single assembly consisting of two germanium crystal diodes. Matched for similar values of forward resistance under conditions typical of actual use.

1N40 A network of 4 carefully selected and matched germanium crystal diodes. Plug-in type—crystals mounted in compact metal shell with small wafer octal base. For use as ring

1N41 Composed of the same carefully matched germanium crystal diodes as the 1N40, the 1N41 is designed for use where top or sub-panel

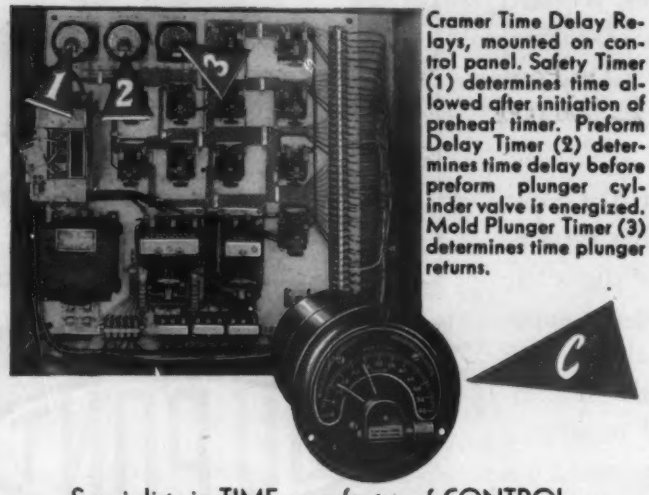
TIME as a factor of CONTROL in Industry

NEW ROCKFORD 4 - FUNCTION MOLDING MACHINE FOR THERMOSETTING PLASTICS ... *timed by Cramer*



Mounted on push button panel . . . Cramer Time Delay Relay determines amount of time delay between two operation cycles.

Measuring, preforming, preheating, molding — the four functions of molding thermosetting plastics combined in one machine! A development of the Rockford Machine Tool Co., all movements are hydraulically powered, electrically controlled . . . automatically timed through the complete operating cycle.
Cramer Time Delay Relays handle four vital timing applications on this unique Rockford Hi-Jector. Another product where dependable control is essential to performance . . . **timed by Cramer.**



Cramer Time Delay Relays, mounted on control panel. Safety Timer (1) determines time allowed after initiation of preheat timer. Preform Delay Timer (2) determines time delay before preform plunger cylinder valve is energized. Mold Plunger Timer (3) determines time plunger returns.

Specialists in TIME as a factor of CONTROL, Cramer has developed a wide range of devices for a great variety of commercial and industrial duties. If the performance of your product depends on precision timing, consult Cramer.

Cramer
THE R. W. CRAMER COMPANY, INC.
Box No. 2, Centerbrook, Conn.

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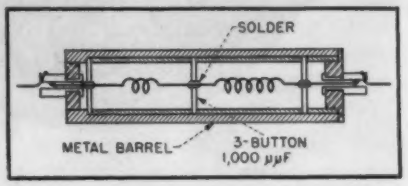

FIG. 3—Details of the microwave filter

detect any type of interference over the entire band from 200 to 1,600 kilocycles; although, by opening the door by as much as one-eighth of an inch several broadcast stations could be received with considerable volume. Moreover, the uhf type of interference was reduced to a negligible amount when the door of the room was securely closed.

X-Ray Speeds Chemical Comparisons

DETERMINATION of the tetraethyl lead content of gasoline, the concentration of an acid in water, the percent chlorination of a plastic, or the percent ash in coal is being done by measuring and comparing the x-ray absorption of a sample and a reference by the use of an x-ray photometer.

The method employed is an outgrowth of wartime experience with the x-ray method of checking the explosive charge in hand grenade fuses to prevent premature detonation. Engineers of General Electric then devised a production system of testing which made it possible to check fuses with x-rays accurately at a rate of 4,000 per hour. Experience with this apparatus led

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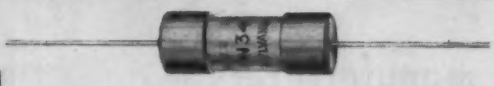
Sylvania's COMPLETE line of Germanium Crystal Diodes

DIODES



1N34 The popularly-priced answer to diode problems in circuits involving up to 60 volts negative potential. Requires no mounting hardware, no heater supply. Has low shunt capacity, no contact potential, convenient pigtail leads. Weighs less than a penny.

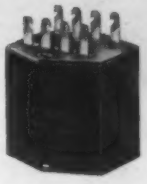
1N38 Ideal for low power rectification from zero to several hundred megacycles. Withstands peak voltages as high as 100 volts. Average life more than 5,000 hours. Can be operated with both terminals above ground.

1N39 Designed for exceptionally high back voltages. Ideally suited for use in switching, waveshaping, coupling and clamping circuits involving negative voltages as high as 200. Mechanically identical to 1N34 and 1N38.

DUO-DIODES *and* VARISTORS

1N35 A single assembly consisting of two germanium crystal diodes. Matched for similar values of forward resistance under conditions typical of actual use. Back resistance of each crystal is greater than 0.8 megohms at −10 volts. Permits compact packaging of balanced circuits for full-wave rectification, modulation or demodulation.

1N40 A network of 4 carefully selected and matched germanium crystal diodes. Plug-in type—crystals mounted in compact metal shell with small wafer octal base. For use as ring modulators and bridge circuits in communications modulation and demodulation, and for application in many other networks requiring highly polarized non-linear characteristics.



1N41 Composed of the same carefully matched germanium crystal diodes as the 1N40, the 1N41 is designed for use where top or sub-panel mounting is preferred. The crystals are assembled in a rectangular metal can. Connections are brought out to eight soldering lugs. Mounting holes provided at top and bottom of metal can.

To save time, space and money, engineer these Sylvania germanium crystal diodes into your products. They are the modern answer to diode problems. Inquiries are invited on special requirements.

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Gentlemen: Please send me copy of bulletin EC-36, "Germanium Crystal Diodes."

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A chemist places cell in position for an x-ray comparison test

to the development of the x-ray photometer by the company's General Engineering and Consulting Laboratory.

Essentially, the device consists of a source of x-rays, a fluorescent screen, a multiplier phototube, an electronic amplifier and an indicating instrument. The x-ray beam is interrupted by a synchronous motor-driven chopper so that half of the beam passes alternately through each of two analyzer cells, one containing the reference and the other containing the sample. In the half of the beam passing through the reference there is placed also an aluminum attenuator disc, the angular position of which corresponds with a particular thickness of metal.

X-rays from the two halves of the beam are received alternately on the fluorescent screen, from which the fluorescence is transmitted to the multiplier phototube. The output of this tube passes through an amplifier to a peak comparator where it registers on a microammeter as a d-c signal indicating the difference in intensities of the two halves of the beam.

Interpretation

If the sample and the reference are identical, the intensities of the two halves of the beam as received on the fluorescent screen are equal and the meter reading is zero without the use of the aluminum atten-

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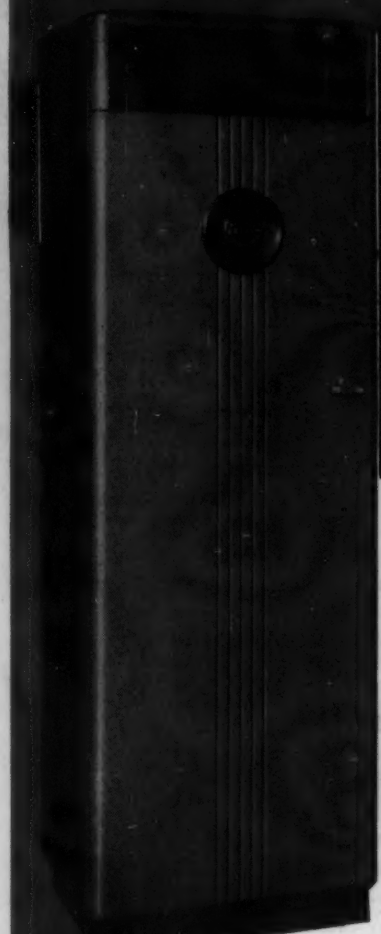

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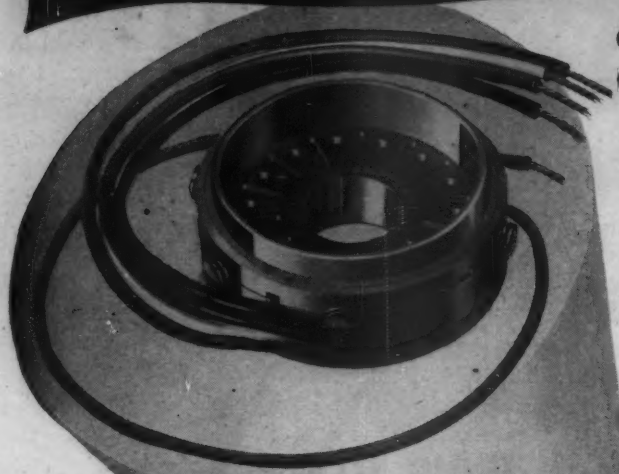
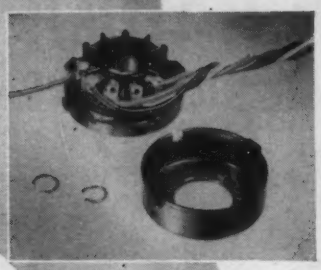


DUODECAL
AND
DIHEPTAL



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Diheptal Tube Sockets: Made in two sizes, for small (2.050 inch) diameter tube bases, also for medium (2.250 inch) diameter bases. Both provide for a maximum of fourteen pins on a 1.750 inch diameter pin circle.

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uator disc. If the sample and the reference are different, it becomes necessary to introduce aluminum by means of the attenuator until the two halves of the beam become of equal intensity and the reading returns to zero. From the thickness of aluminum introduced into the reference half of the beam, it is possible to determine empirically the proportion of certain elements in the sample as compared with the reference. In general, the method is most applicable where there is a considerable difference in the atomic numbers of the main substance and the particular ingredient to be measured.

Under most circumstances, the limiting factor to rapid operation has been found to be the time required for the preparation of the sample. Liquids must be measured as they are put into the analyzer cell and require more time than solids when the latter are specimens of uniform thickness. Powdered solids such as coal, which must be weighed into the analyzer cell, require more time than liquids. If preparation of the samples can be arranged independently of the operation of the instrument, there is no difficulty in maintaining a six per hour rate regardless of the physical form of the material to be tested.

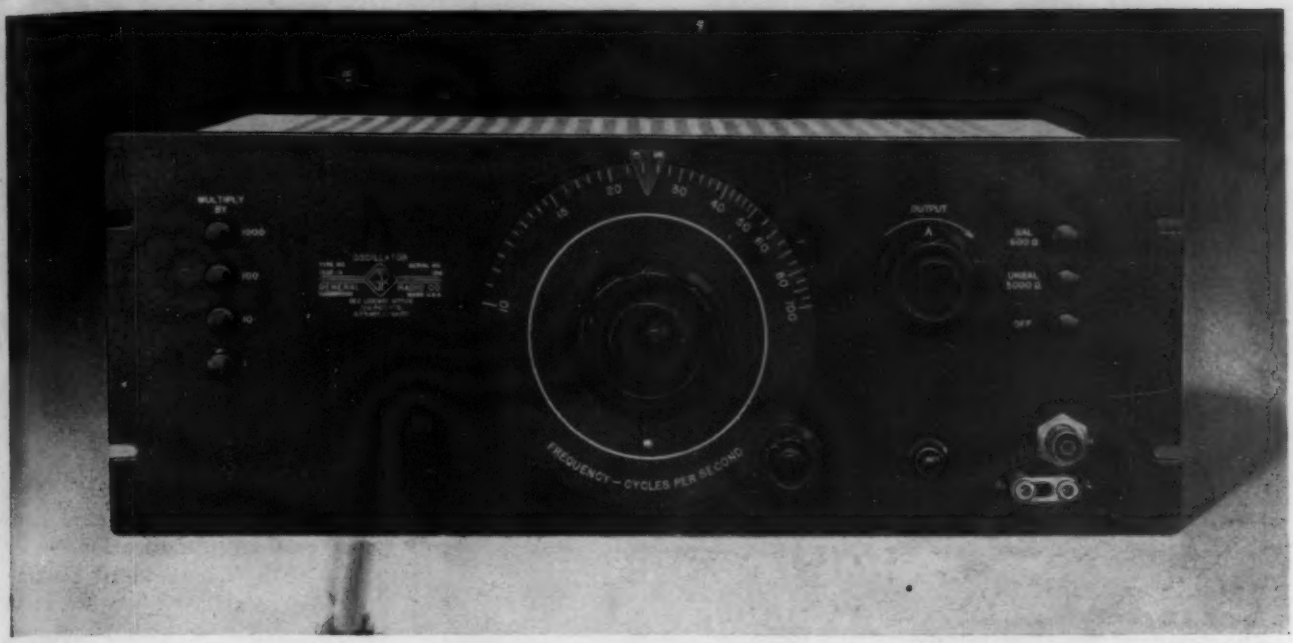
One advantage of this method of comparison is that it is independent of the physical state of the substance being tested, because the amount of x-ray absorption by a given mass of material is always the same, whether the material is hot or cold, gaseous, liquid, or solid.

Polarity Response from Tuning Eye Tubes

By M. L. Greenough
Electronic Instrumentation Laboratory
National Bureau of Standards
Washington, D. C.

Polarity-sensitive indication of discriminator tuning in f-m reception is provided by the new 6AL7-GT indicator tube having a dual-column type of presentation. For instrument work, however, a balance indicator capable of greater precision is frequently desired.

By means of the circuit shown in Fig. 1, a conventional tuning-



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With a single dial and four push-button-controlled multipliers, the Type 1302-A Oscillator covers the range of 10 to 100,000 cycles. Because of its wide frequency range and flat output this oscillator is particularly suited to taking frequency response characteristics on amplifiers, telephone lines, filters and other such circuit elements.

FEATURES

- **WIDE FREQUENCY RANGE**—10 to 100,000 cycles—180-degree rotation of dial covers the 10 to 100-cycle decade—panel push buttons add in decade steps
- **ACCURATE CALIBRATION**—adjusted within ±(1-1/2% + 0.2 cycle)
- **LOW DISTORTION**—less than 1% at any frequency
- **SMALL FREQUENCY DRIFT**—less than 1% in first 10 minutes; less than 0.2% per hour afterwards
- **FREQUENCY DRIFT CONSTANT PERCENTAGE OF OPERATING FREQUENCY**—particularly helpful with bridge measurements at low frequencies
- **CONSTANT OUTPUT VOLTAGE**—within ±1.0 db over whole range; 20 volts open circuit on 5,000-ohm output, 10 volts on 600 ohm
- **STABILIZED SUPPLY**—compensated for transient line voltage surges and average line voltage variations between 105 and 125 (210 and 250) volts
- **VARIABLE CONDENSER FREQUENCY CONTROL**—avoiding contack difficulties often found in variable resistance control
- **TWO SEPARATE OUTPUT CIRCUITS**—balanced 600 ohm and unbalanced 5,000 ohm

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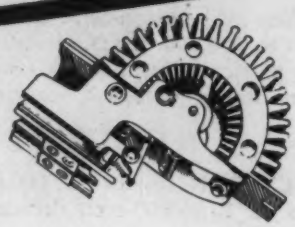

Due to changes in temperature and humidity, difficulty is often encountered with laminated plastics "flowing" in relay pile-ups and stepping switches. In order to overcome this instability, National research engineers have worked painstakingly to develop Grade XXX-402 Phenolite, laminated plastic, which possesses exceptionally low cold flow and remarkable dimensional stability under varying degrees of temperature and humidity.

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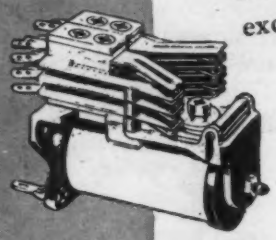

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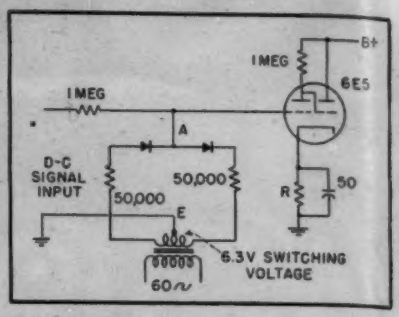

FIG. 1—With this circuit, positive or negative signals can be indicated on a conventional tuning-eye tube. Value of *R* is determined by available plate voltage

eye tube of the 6E5, 6U5, 6N5 series can be used to furnish a polarity-sensitive indication.

The obvious method of making the tube polarity-responsive is to bias the deflection grid to produce some arbitrarily chosen reference angle, which is marked on the scale over the tube. Positive or negative signals then cause an increase or a decrease of this shadow angle. The disadvantages of such a system are the instability of the reference angle, which is greatly dependent upon the supply voltages, and parallax of observation.

These disadvantages may be avoided by repeatedly switching the signal on and off at a rate fast enough to prevent visible flicker, for example, at power line frequency. By this means two shadow angles are maintained on the tube screen itself. One shadow angle, corresponding to zero input, appears half the time, while during the remaining time the angle is that due to the amplitude of the applied signal. Zero signal input is indicated when the edges of these angles coincide.

Typical patterns obtained for positive, zero and negative signals are shown in Fig. 2. There appears to be a half-illuminated angular sector whose width is proportional to the deflection signal, and which lies on one or the other side of a reference line as determined by signal polarity. Alternatively, the pattern may be considered as two superimposed areas of half-illumination, one fixed and one variable. The edges of these areas are similar and sharp in the 6E5 and their superposition at balance can be precisely observed.

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tained in spite of supply voltage variations, since such changes merely affect both illuminated areas identically. Using reasonable care it has been found possible to repeat observations of balance to less than 0.05 volt with the unaided eye. A simple lens permits resolution approaching an electrically imposed limit, which in this case was measured to be approximately 7 millivolts. Although no extended study of ultimate balance limitations has been made, higher magnification and improved switching circuits could undoubtedly provide higher resolution.

In the circuit shown, the diode network acts effectively as a switch which is opened and closed during alternate half cycles of the 60-cps switching voltage. The d-c input signal is applied across the 1-megohm resistor in series with the

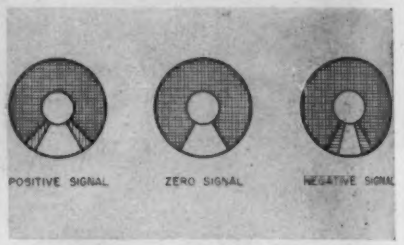

FIG. 2—Pattern on 6E5 tube when connected in polarity responsive circuit

resistance of the diode switching circuit between point *A* and ground. The voltage across the diode switching circuit is applied to the grid of the tuning eye.

During the half cycle of switching voltage which renders the diodes conducting, the resistance between point *A* and ground is low relative to 1 megohm. This permits a negligible fraction of the input voltage to appear between point *A* and ground.

During the half cycle of diode nonconduction, the resistance of each diode is increased to its reverse voltage value, and nearly the entire input voltage appears between point *A* and ground. Due to the symmetry of the diode network, none of the switching voltage appears between point *A* and ground.

In this circuit diodes of high quality, particularly with regard to back resistance, provide maximum sensitivity of indication. Miniature dry-disc rectifiers, for

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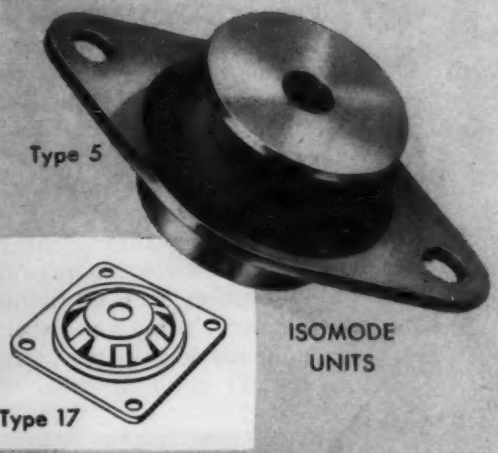

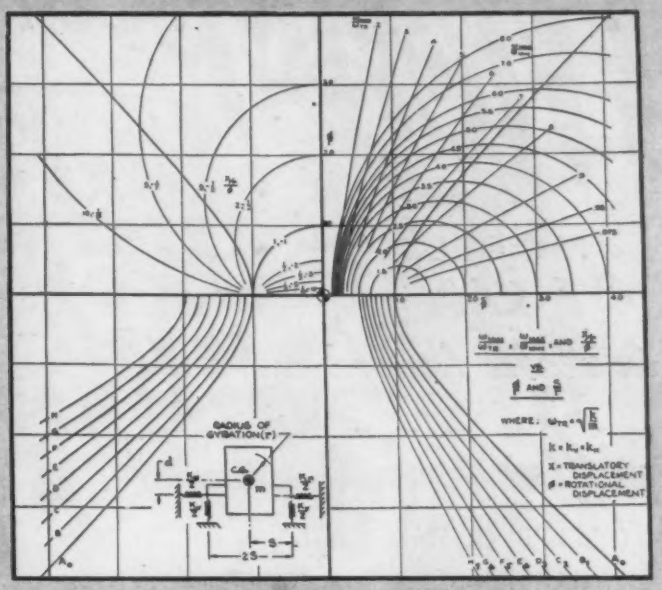

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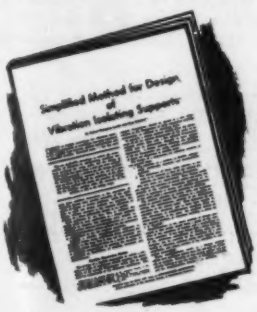

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example 7-mm selenium or copper oxide units having more than 10 megohms back resistance, have proved satisfactory.

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Conventional methods of test viewing using block houses for the observers employ laminated safety glass which becomes clouded from close-range effects of propellant fumes, or using mirrors which in addition to becoming clouded limit the range of vision and often include distortion. Both of these systems require apertures through heavy safety walls of the block house thereby weakening the structure. Observation is also limited to two or three persons per aperture.

In the television method, safety is assured by the remoteness of the

For the rocket tests, a standard image-orthicon camera was mounted on a regular studio dolly and wrapped in sponge rubber padding. The video signal was fed by coaxial cable to three 10-inch kinescopes

viewing operation and picture light intensity and definition are far superior to direct viewing through glass. Other advantages of the television method are important to the test engineers. With a closeup view provided by the television

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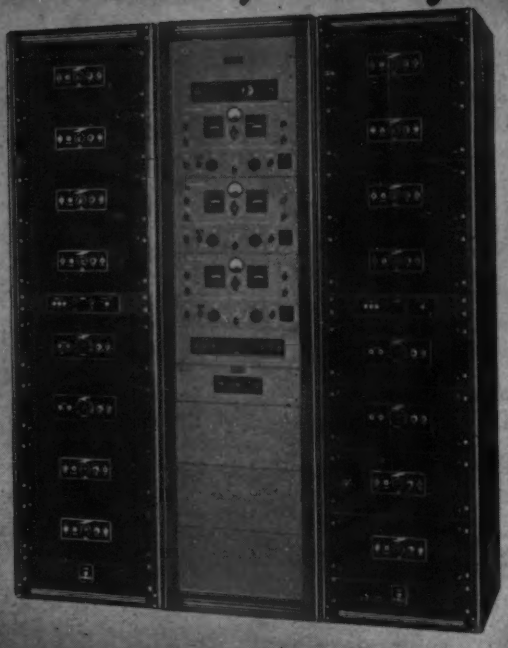

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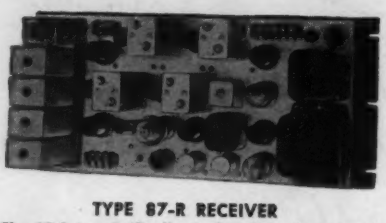
An outstanding development is the new, all crystal controlled 250-T exciter. New highs in stability have been achieved and all forms of spurious output frequencies eliminated. Instant selection of three operating channels, each preset to its individual carrier frequency and Mark-Space shift requirement, is available.

Receiver converter 216-S is used with the 87-R receiver and its output functions will drive a teletype printer, tape recorder or tone oscillator. This combination can be implemented on diversity or non-diversity telegraph circuits.

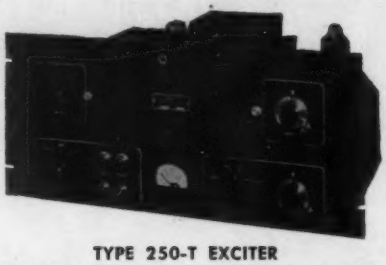
In addition to above, we manufacture a complete line of tone converters, transmitters, VHF channeling equipment and other apparatus for high speed telegraph communication. Write for literature.

Typical of their adaptability, standard Erco units were combined into this packaged receiving station which provides multichannel dual diversity reception of high speed radio type FST signals.



TYPE 87-R RECEIVER

The 87-R is specifically designed for the reception of high speed FST signals where a high degree of stability, sensitivity and selectivity is required under continuous operating conditions.



TYPE 250-T EXCITER

The 250-T all crystal controlled exciter is designed to key a radio telegraph transmitter by the frequency shift method and replaces the existing oscillator in the transmitter.

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camera, engineers can detect in time to stop the test firing any evidence of fuel leaks or malfunctioning of the system which could result in an explosion and major damage to the rocket motor and its test setup. Observation of the rocket and exhaust flames during the firing period also enables test engineers to note any irregularities in mixture ratio.

Numerous possibilities for industrial applications of television are: salvage of ships or underwater exploration, some mining operations and rescue work; where danger exists from possible explosions, fire, dust, as in certain operations in steel mills, chemical plants, glass factories, and where remote supervision is necessary as at dams, vehicular and railroad tunnels, and traffic control.

The rocket tests were monitored by television equipment supplied by General Electric Company for a demonstration to government officials at the proving grounds of Aero Jet Engineering Corp. at Azusa, California.

•

SURPLUS GROUND PLANE

Wide changes in moisture content caused the glide path course to lower as much as 150 feet at the outer marker at this Landing Aids Experiment Station at Arcata, California. Since installation of surplus landing mats around the station the weather has caused no shift at all. The pad is 100 feet wide at the antenna, fans out to 200 feet at a distance of 200 feet

WEBSTER ELECTRIC

IT'S NEW! Featheride

Retractable Cartridge!

a crystal cartridge THAT PROTECTS RECORD AND NEEDLE . . .

You'll be pleased with the exceptionally quiet playing and ideal response characteristics of the "Featheride" retractable cartridge. This new cartridge has a light tracking pressure (¾ ounce) and is supplied in 1 v. and 2 v. models. It has the same high quality that characterizes the entire Webster Electric line. The "Featheride" retractable cartridge comes with a special osmium-tipped offset needle, needle guard and necessary attachments for retractable feature. In case an individual should drop or slide the pickup, it will not damage the record or needle.

For full information write Webster Electric Company, Racine, Wisconsin.

(Licensed under patents of the Brush Development Company)

WEBSTER RACINE **ELECTRIC** WISCONSIN

Established 1909

featuring . . .

- √ Light tracking pressure
- √ High lateral and vertical compliance
- √ Minimum needle and mechanical noise
- √ Available with correct response characteristics
- √ Provided with offset needle
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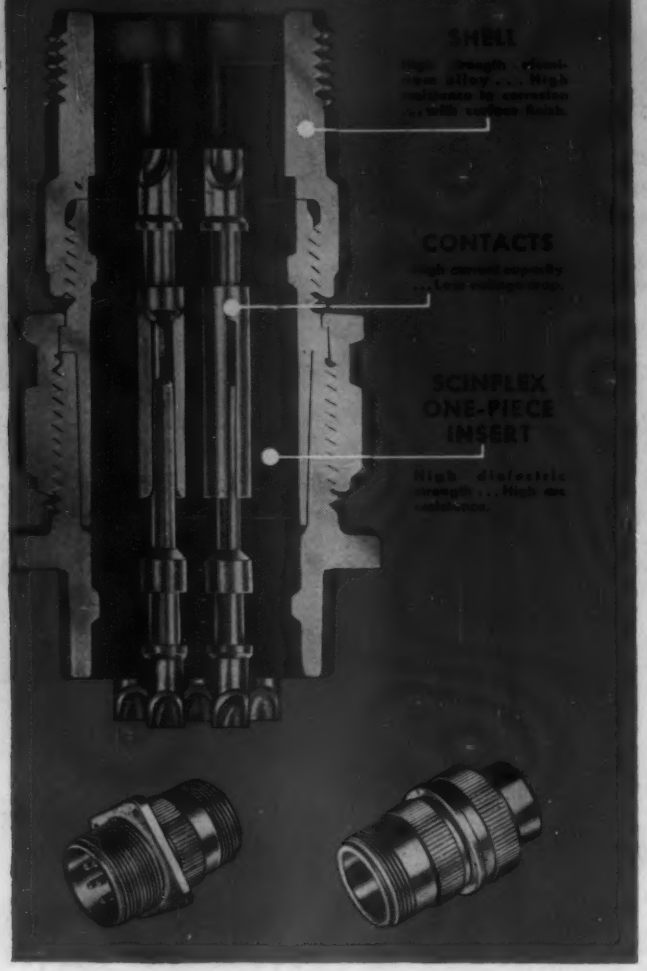
the finest ELECTRICAL CONNECTORS money can build or buy!



AND THE SECRET IS SCINFLEX!

Bendix-Scintilla* Electrical Connectors are precision-built to render peak efficiency day-in and day-out even under difficult operating conditions. The use of "Scinflex" dielectric material, a new Bendix-Scintilla development of outstanding stability, makes them vibration-proof, moisture-proof, pressure-tight, and increases flashover and creepage distances. In temperature extremes, from —67° F. to +300° F., performance is remarkable. Dielectric strength is never less than 300 volts per mil.

The contacts, made of the finest materials, carry maximum currents with the lowest voltage drop known to the industry. Bendix-Scintilla Connectors have fewer parts than any other connector on the market—an exclusive feature that means lower maintenance cost and better performance.

*REG. U.S. PAT. OFF.

Write our Sales Department for detailed information.

• Moisture-proof, Pressure-tight • Radio Quiet • Single-piece Insert • Vibration-proof • Light Weight • High Arc Resistance • Easy Assembly and Disassembly • Less parts than any other Connector

Available in all Standard A.N. Contact Configurations

BENDIX SCINTILLA — SCINTILLA MAGNETO DIVISION OF — SIDNEY, N. Y.

(continued from page 140)

Crystals in holders respond quickly to alpha radiation, much as do G-M tubes

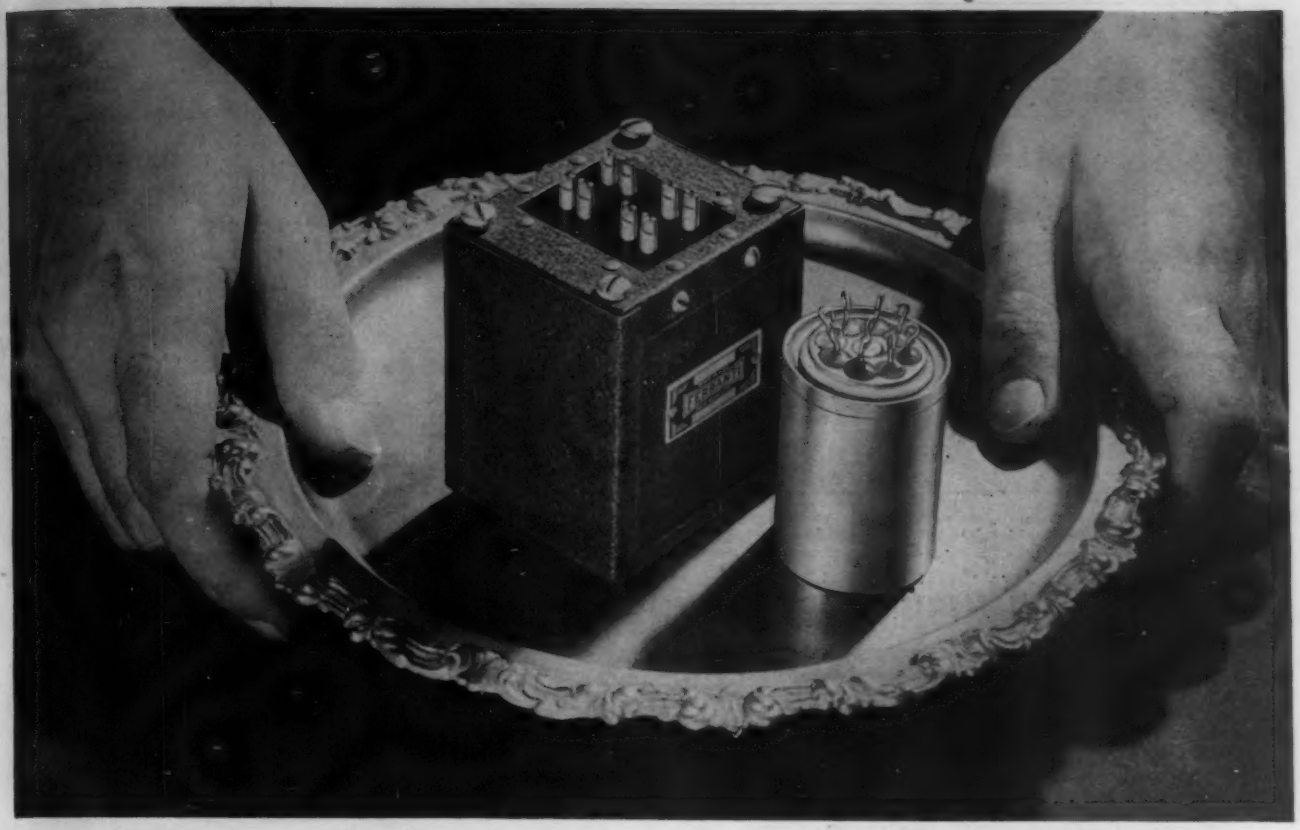
supplementing existing techniques. It also provides physicists with a powerful tool with which to learn more about the fundamental structure of solid matter.

Experiments, described before the American Physical Society, in which electric currents shot at a diamond chip are amplified by as much as 500 times, are conducted in a cathode-ray tube. The 15,000 electron-volt beam is directed at a diamond crystal that is about a quarter of an inch square and 20 thousandths of an inch thick. As the current starts to flow under the bombardment, electrons become trapped in the imperfections of the crystal. Consequently the induced current is reduced. To overcome this, alternating current is applied to the crystal. Alternately negative and positive charges are drawn through the crystal and some of each polarity are trapped, neutralizing each other so that the full amplification is obtained.

Gold electrodes a hundred-thousandth of an inch thick are evaporated onto the crystal during its preparation for testing to afford electrical connections. Although the crystals are bombarded by pulses of electrons only a microsecond long, the induced currents are produced so quickly that the response time has not been measurable. Earlier experiments used alpha particles to bombard crystals.

Tubes Designed for Industry

UNIFORMITY and stability are being engineered into electronic tubes. Although tubes and other com-



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From our more than 20 years' experience as transformer specialists, come precision transformers of every type—custom-made for YOUR new applications. FERRANTI facilities permit unusual service to each customer, whether large or small, and insure prompt deliveries.

AUDIO TRANSFORMERS **AUDIO FILTERS**
POWER TRANSFORMERS **REACTORS**
HERMETICALLY SEALED WHEN SPECIFIED

We also build power supply units and electronic assemblies to specifications at prices comparable to those of stock assemblies. We invite your inquiries.

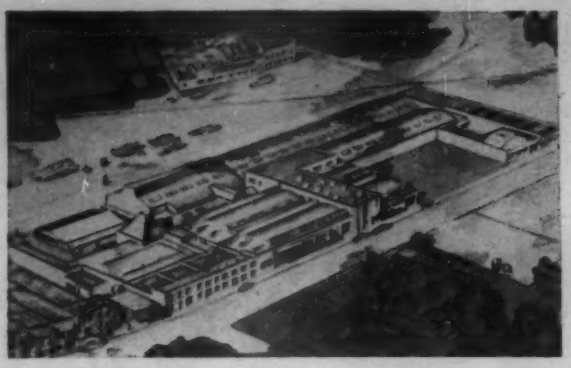
ALSO FOR MODERN HIGH VOLTAGE DEVELOPMENTS WHERE ZERO CURRENT DRAIN IS IMPERATIVE

THE FERRANTI ELECTROSTATIC VOLTMETER

Types available for maximum readings from 150 to 3500 volts. 2½ in. dial, flush mounting, projecting and portable models. Write for informative literature.

• *Ferranti Electric, Inc.* **RCA BUILDING** •

30 Rockefeller Plaza • New York 20, N. Y.



Manufacturing plants of the Cannon Electric Development Company occupy more than one square city block between Humboldt Street, Avenue 33 and Artesia Street in Los Angeles. The old plant, located across the main line Santa Fe tracks, is now used as a warehouse.

SUPPLIER OF HIGH GRADE CONNECTORS FOR RADIO AND ELECTRONIC EQUIPMENT

SINCE 1915, when Cannon Electric was founded by its president and owner, James H. Cannon, at that time manufacturing signal equipment and electrical specialties, the company has grown steadily until it stands among the top ranks of manufacturers of electrical components over the nation.

Cannon Electric makes not only multi-contact electric connectors, but direct-current solenoids, signal equipment for hospital and industrial buildings, various lights, conduit fittings, specialized relays, and certain hardware items. Ask for the Cannon Electric Condensed Catalog for a survey of our products.

XL-3-12 Plug in the "XL" Series

03-11 Plug in the "O" Series

P3-CG-12S Plug in the "P" Series

X-3-11 Plug in the "X" Series

KNOW CANNON ELECTRIC SALES PERSONNEL

DON A. DAVIS, *Sales Manager*

For more than six years a member of the sales-engineering staff of Cannon Electric, Don A. Davis is a graduate engineer with wide experience in aircraft and electrical fields. Mr. Davis combines the qualities of a sales executive with knowledge and experience in electrical design and engineering.

CANNON ELECTRIC *Development Company*

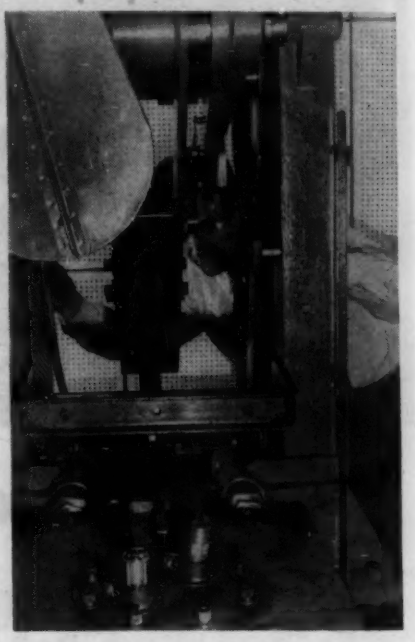
SINCE 1915

3209 HUMBOLDT ST., LOS ANGELES 31, CALIF.

IN CANADA & BRITISH EMPIRE: CANNON ELECTRIC COMPANY, LTD. TORONTO 13, ONTARIO

WORLD EXPORT (excepting British Empire): FRAZAR & HANSEN, 301 CLAY STREET SAN FRANCISCO 11, CALIFORNIA

ponents of electronisms, if operated within their ratings, do not usually fail, their failure does interrupt the equipment they are controlling. In a domestic radio, such failure is of little consequence, aside from limited personal inconvenience, but, in industrial control equipment and such complex electronic devices as computers[1], interruptions may delay the work or threaten the safety of many peo-



Tests at RCA Labs. indicate that special tubes withstand repeated impact shocks of 100g for extended periods

ple. For example, the dependence placed on airborne electronic equipment justifies developing ruggedized tubes[2]. In fact, the importance of dependability in equipment intended for industrial use requires a radically different approach to its design than that for home radios on which most electronic designers have cut their eye teeth.

Toward meeting this need of industrial electronic equipment, a few special tube types have been designed to have a minimum useful life of 10,000 hours (14 months of continuous operation) and enough rigidity to resist usual industrial mechanical shocks and vibrations. Electrically these tubes are comparable to the 6SL7-GT, 6SN7-GT, and 6SJ7[3]. In part, the improved dependability of these tubes has been obtained by carefully controlled production and extensive testing from initial selection of materials through assembly

ARNOLD

Specialists and Leaders in the Design, Engineering and Manufacture of PERMANENT MAGNETS

Arnold's business is permanent magnets, *exclusively*—a field to which we have contributed much of the pioneering and development, and in which we have set peak standards for quality and uniformity of product.

Our service to users of permanent magnets starts at the design level and carries on to finish-ground and tested units, ready for your installation. It embraces all Alnico grades and other types of permanent magnet materials—any size or shape—and any magnetic or mechanical requirement, no matter how exacting.

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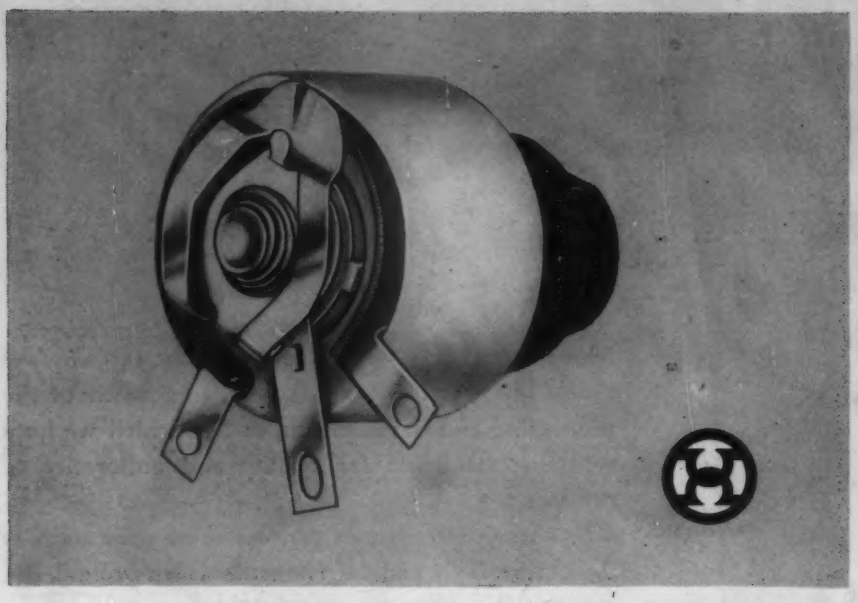
Specialists and Leaders in the Design, Engineering and Manufacture of PERMANENT MAGNETS

W&D 1100

Maximum Wattage Dissipation for Size



THIS COMPACT, rugged type M 25 watt rheostat offers exceptional heat dissipation. An exclusive Hardwick, Hindle feature is the lock tab which prevents deformation of the contact arm due to rough handling. Its steel stop pin will withstand over 40 inch pounds torque.

The resistance element is wound on a pure mica strip, embedded in vitreous enamel and sealed in a ceramic base—thus bonding inseparably the winding and base.

And in our type M rheostats you have a choice of 2 types of contact mechanisms, either a carbon brush or a spring metallic contact. And also a choice of 2 types of bases designed for either lug type or screw type terminals, or any combination thereof.

Other types of Hardwick, Hindle rheostats, and our many resistors offer you valuable exclusive advantages.

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HARDWICK, HINDLE, INC.

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Subsidiary of

THE NATIONAL LOCK WASHER COMPANY

NEWARK 5, N. J. Established 1886 U. S. A.

Metal stops, welded to the grid rods, bear against mica supports to prevent motion

and final processing. Dependability of industrial equipment using these tubes can be obtained by the same basic method.

Electrical uniformity is dependent on stable cathode emission[4]. For these tubes, the cathodes have been designed to operate at lower temperatures than in other tubes, and their processing is controlled to prevent cathode materials from depositing on other electrodes. The control grids are plated to minimize variations in contact potential. Pure tungsten heaters assure long life despite frequent switching on and off. The tubes are produced on a special assembly line by trained personnel, manufactured more slowly than standard types; every one is tested, instead of each batch being sampled. Such production is costly, but tubes (and equipment) built to close tolerances are industrially economical.

An embossed ring in the upper end of each cathode anchors it to the upper mica to reduce variations in the tube's characteristics during vibration. In the twin triodes, eyelets in the micas prevent wearing of the mounting holes. Two getters assure a good and permanent vacuum. An extra mica disc prevents getter material from reaching the electrodes. In the sharp cutoff pentode, an A-frame welded to the steel ring on the stem rigidly supports the electrodes[5]. As a consequence these special tubes withstand continuous vibrations at 20 cycles per second of 2.5g for hundreds of hours at maximum rated voltages. They will survive shocks

hp SETS A NEW PERFORMANCE STANDARD!
YOU GET ALL THESE FEATURES IN THIS NEW HIGH FIDELITY SIGNAL GENERATOR
Voltage accurate within 0.2 db
Distortion less than 0.1%
Continuously variable a-f voltage
Frequency range 20 cps to 20 mc
High stability of frequency
-hp- 206A Audio Signal Generator

For the first time *all* the features listed above are combined in one precision instrument, to give you signals of *utmost purity and accuracy* for high fidelity measuring work.

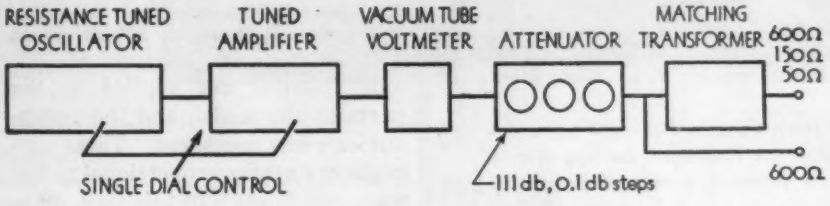

Figure 1 — Circuit Structure of *-hp-* 206A Generator

In addition, the new *-hp-* 206A Generator includes low-temperature coefficient frequency determining elements for high stability and unvarying accuracy over long periods of time. A precision attenuator varies output signal level in 0.1 decibel steps throughout 111 decibels.

Resistance-tuned Oscillator

The resistance-tuned oscillator is followed by an automatically tracked amplifier whose high selectivity reduces oscillator harmonics. Following the 111 db attenuator is a transformer which can be matched to loads of 50, 150 and 600 ohms. A 600 ohm single-ended output is also provided (Fig. 1).

Specially designed for testing high quality audio circuits, the *-hp-* 206A is ideal for FM transmitter maintenance, studio amplifier and corsole testing, a source for bridge measurements, a-f voltage or transmission measurements; and for other applications requiring a very low distortion signal of known amplitude.

Full details available on request

HEWLETT-PACKARD CO.
1640A Page Mill Road, Palo Alto, California
Export Agents: Frazar & Hansen, Ltd.
301 Clay Street • San Francisco, Calif., U. S. A.

SPECIFICATIONS

FREQUENCY RANGE: 20 cps to 20 kc, 3 bands.

CALIBRATION: Direct in cps on lowest band.

STABILITY: Better than 2%. Low temperature coefficient frequency network.

OUTPUT: +15 dbm into 50, 150, 600 ohms. Approx. 10 v into open circuit.

OUTPUT IMPEDANCE: 50, 150, 600 ohms balanced. 600 ohms single ended. Matched internal impedances.

FREQUENCY RESPONSE: Within 0.2 db, 30 cps to 15 kc, beyond meter, at all levels.

DISTORTION: Less than 0.1% above 50 cps. Less than 0.25% below 50 cps.

HUM LEVEL: 70 db below output signal, or 100 db below zero level.

OUTPUT METER: Reads in dbm or volts.

ATTENUATORS: 111 db in 0.1 db steps. Accuracy approximately 0.1 db.

hp laboratory instruments
FOR SPEED AND ACCURACY

Power Supplies *Frequency Standards* *Amplifiers* *Electronic Tachometers* *Frequency Meters*
UHF Signal Generators *Square Wave Generators* *Audio Frequency Oscillators* *Attenuators*
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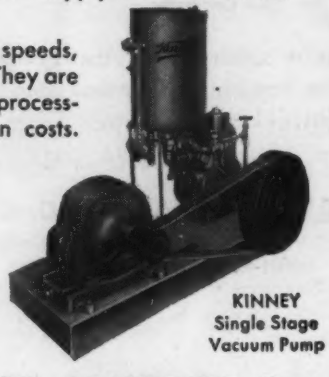
LOW PRESSURE PROCESSING SOLVES A MAJOR PROBLEM

One of the newer applications of Kinney High Vacuum Pumps is the automatic vacuum treating of sealing oil used in the hydrogen cooling system of large turbine generators. Here, the low pressure treatment constantly removes water and entrained gas from the vital oil supply to assure efficient sealing of the hydrogen system.

For compactness, reliability and high pumping speeds, Kinney High Vacuum Pumps are unsurpassed. They are serving countless industries where low pressure processing simplifies operations and cuts production costs. Among their better known applications are exhausting lamps and tubes, sintering alloy metals, coating lenses, dehydrating foods, producing drugs, etc. Kinney Single Stage Vacuum Pumps produce low absolute pressures to 10 microns; Compound Pumps to 0.5 micron.

Write for Bulletin V45



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WE ALSO MANUFACTURE LIQUID PUMPS, CLUTCHES AND BITUMINOUS DISTRIBUTORS

of 100g for extended periods or 500g for short periods.

(1) F. R. Michael, Tube Failures in ENIAC, ELECTRONICS, p 116, Oct. 1947.
(2) Frank Rockett, How's and Why's of Aircraft Tubes, *Aviation*, p 85, Apr. 1947.
(3) Booklet RSB-1000, RCA Special Red Tubes, Tube Department, Harrison, N. J., 1948.
(4) Improvements in Small Tubes, ELECTRONICS, p 144, Nov. 1947
(5) I. L. Cherrick, Rugged Electron Tubes, Electronics, p 111, Apr. 1948.

Magnetic Leakage Evaluated with an Electrolytic Tank

By F. LEVI
Research and Design Engineer
Rola Company, Pty. Ltd.
Richmond, Victoria, Australia

LEAKAGE AND USEFUL FLUXES in permanent-magnet circuits can be determined approximately with an electrolytic tank. A model of the magnetic circuit, built in a particular manner, is immersed in an electrically conductive medium. Suitable voltages are applied to the parts of the model, and the resultant currents measured. These currents are nearly proportional to the magnetic fluxes. In this way, magnetic circuits can be tested prior to their actual construction, and the effects of design parameters studied conveniently.

Experimental equipment for electrolytic tank testing of permanent magnet circuits

Basis of Method

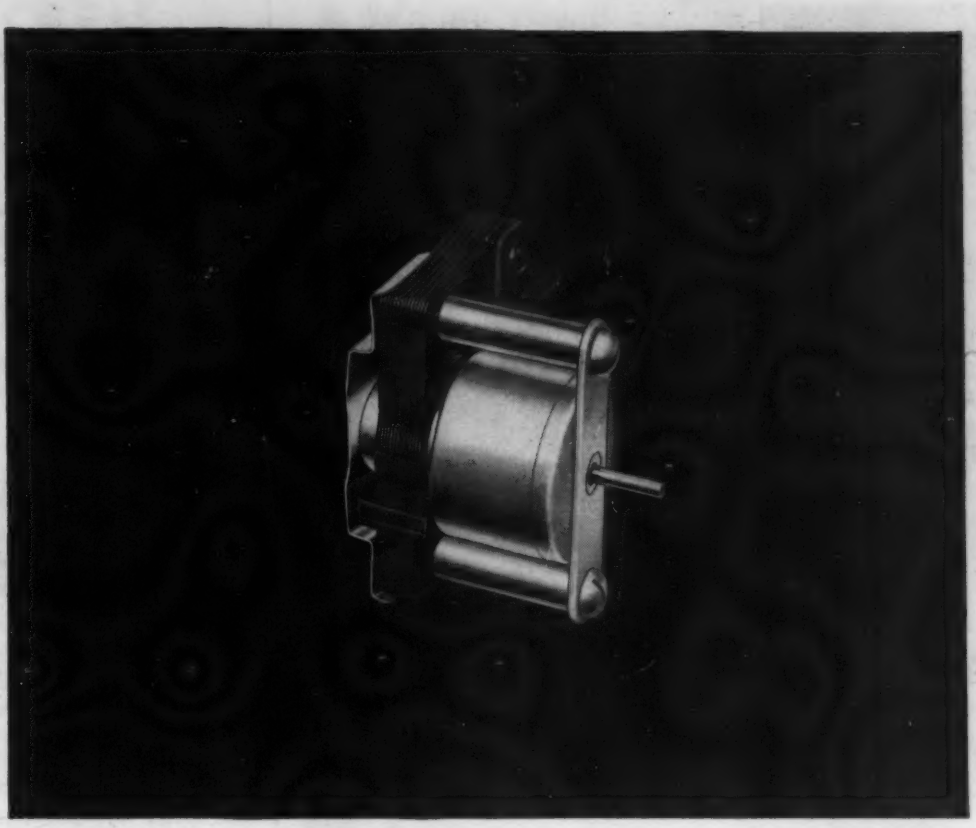
To reduce the magnetic circuit to sufficiently simple form so that the electrolytic tank can be easily used, the fundamentals of permanent-magnet design and the graphs for empirical estimation of two leakage factors presented by Underhill[1] are used. The first of these factors is

$$F = \text{Total Flux} / \text{Useful Flux}$$

and it is governed by the relative position of the surfaces of the magnetic circuit as well as by the difference of magnetomotive force between them. It varies between wide limits, about from 2 to 20, and

For a host of domestic and industrial applications

A new ½ rpm motor by *Telechron*



HERE'S a brand-new Telechron synchronous electric motor that will find many important uses—an accurate, long-life motor with a terminal-shaft speed of ½ rpm.

This latest Telechron model was developed especially for use in domestic oil-burner controls, in commercial stokers and oil burners, in delayed-action relays in industrial control mechanisms. It is readily adaptable to many timing, switching, recording and control equipment.

Like all Telechron motors, the new ½ rpm model is self-starting and reaches synchronous speed almost instantly. Its conservative torque rating insures dependable operation. Since it operates in perfect synchronism with all commercial frequencies, *it can't run faster or slower.* Precision engineering and building, coupled with Telechron's exclusive oiling system, assure years of trouble-free service.

For over 25 years, Telechron has been the largest producer of synchronous electric motors. Every one is Underwriters Laboratories approved. That's your assurance of accurate service, low-cost maintenance. Why not let Telechron *application engineers* answer your timing questions? Address Motor Advisory Service, Dept. M, Telechron Inc., Ashland, Mass.

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Research in Nuclear Physics Always Involves the Problem of Personnel Protection

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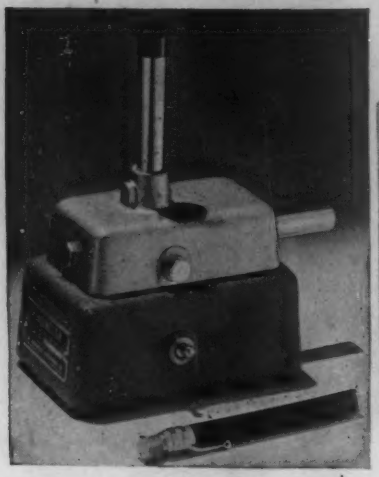

MINOMETER

The Minometer provides a prescription for computing in roentgens the daily exposure to radiation. It consists of a small compact string electrometer and an ionization chamber designed in the shape of a fountain pen to be carried conveniently in a pocket.

The chamber value is 0.2 r full scale when checked against the calibrated scale in the electrometer. For special purposes a 0.01 r and a 0.001 r chamber are supplied.

PROTEXIMETER

The Proteximeter is advantageous in monitoring scattered x radiation or gamma rays at any location adjacent to the radiation source. It measures such scattering accumulatively the quantity indicated visually on a calibrated meter scale.

The scale is calibrated in milliroentgens with full scale deflection 200 milliroentgens or 0.2 r, which is double the accepted value for a daily tolerance dose. The externally mounted ionization chamber is hermetically sealed.

• •

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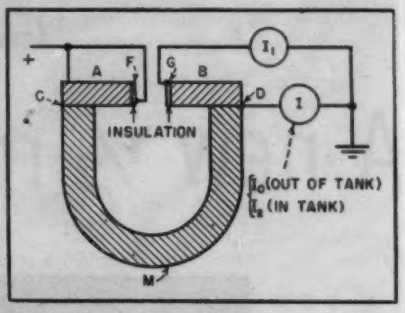


FIG. 1—Construction of magnet model for use in electrolytic tank

its accurate calculation is difficult.[3]

The second factor, defined as

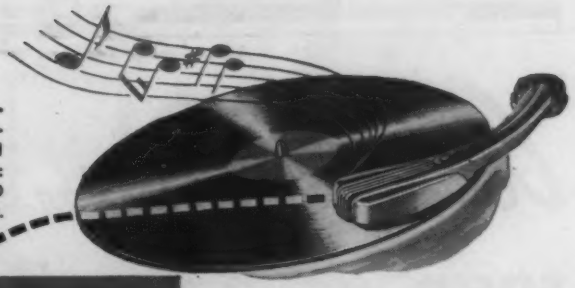
$$f = \frac{\textit{Magnetomotive Force Supplied by the Magnet(s)}}{\textit{Magnetomotive Force Available across the Gap}}$$

accounts for loss of magnetomotive force through the soft iron parts usually present in the circuit. It varies usually between 1.1 and 1.5 and can be computed from knowledge of the magnetic properties, cross sections, lengths, and inductions of the soft iron parts.

If f is not much greater than unity, it is possible to obtain experimentally a fairly accurate estimate of the ratios of the various fluxes in the circuit, and, in particular, of the value of F without actually building the permanent magnet. To do this, one builds a scale model of the permanent magnet circuit so that all the surfaces are electrically conductive and so that there is on them a distribution of electrical potential similar to the distribution of magnetic potential on the corresponding surfaces of the magnetic unit. The model is then immersed in the electrolytic tank for measurement. An example best illustrates the details of the method.

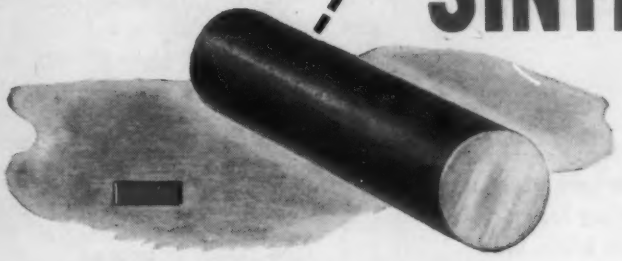
Estimating Leakage Flux

To estimate the flux leakage factor F of a magnetic circuit consisting of a horseshoe magnet and two soft iron pole pieces, one builds a scale model as shown in Fig. 1. The pole pieces A and B are made either of a conductive material like copper or of an insulating material with a conductive coating such as copper-plated wood. Two copper shims F and G, cemented on the pole pieces and insulated from them, cover the area which, in the magnetic circuit, is crossed by the useful flux. The magnet M is built of insulating material, with a uni-



The G-E Electronic Reproducer, which magnetically recreates the full recorded sound, derives its magnetic field from a G-E SINTERED ALNICO 5 permanent magnet.

Announcing... A NEW G-E DEVELOPMENT SINTERED ALNICO 5



Actual size of G-E SINTERED ALNICO 5 permanent magnet used in the G-E Electronic Reproducer is shown in red.

NEW ENGINEERING DEVELOPMENT

SINTERED ALNICO 5, General Electric's newest magnetic material, now enables you to design intricate shapes with higher external energy than ever before. The minimum guaranteed available energy is 3,500,000 gauss oersteds for most sizes and shapes. New G-E SINTERED ALNICO 5 possesses tensile properties several times those of CAST ALNICO 5 and can be produced economically in small size parts. You get better surface finish plus closer dimensional tolerances with new G-E SINTERED ALNICO 5.

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New SINTERED ALNICO 5 has higher external energy than either SINTERED ALNICO 2 or 4. This makes possible new designs heretofore impossible or impractical. It is especially adaptable where small powerful magnets having high magnetic properties are required. Because of their great stability and external energy, SINTERED ALNICO 5 magnets can save valuable space in your product. You can usually improve your product by re-designing to use high energy G-E SINTERED ALNICO 5. Typical applications now in production which use G-E SINTERED ALNICO 5 include the following: meters, relays, fountain pens, electronic reproducers, and compasses.

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G-E application and development engineers, working closely together, are ready to advise you on new SINTERED ALNICO 5 and other G-E magnetic materials. Our engineers are backed by years of research and the development of thousands of magnetic applications. They will be glad to work with you on your product design. For more information, please mail the coupon shown below.

YOU GET 5 ADVANTAGES

1. Higher external energy than either SINTERED ALNICO 2 or 4.
2. Tensile properties are several times greater than CAST ALNICO.
3. Excellent surface finish.
4. Close dimensional tolerances.
5. Intricate shapes possible.

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Please send me:
( ) Technical Report on new SINTERED ALNICO 5.
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PERMANENT MAGNETS

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CD48-V2

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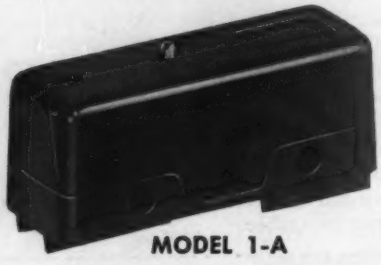
Model "M" with No. A-22 wire Leaf Actuator for coin operated machines. Length and form of wire can be made to suit job.

Standard Model "M" with Pin Actuator. 1 11/64" x 5/64" x 9/32". Four 3/32" mounting holes. Bakelite case. Pin Actuator either stainless steel or all bakelite.

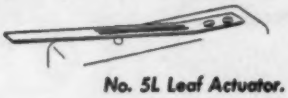
Standard Model "M" fitted with No. A-18 Leaf Actuator Bracket. Also furnished with Roller Leaf. Code: A-18M.

The ACRO Model "M" can be the answer to the designer's prayer because it can be slipped in where no other switch will go. But while it is tiny, it is truly a mighty midget—delivering long, dependable service with extreme accuracy. There is no knife blade or bearing action. ACRO's exclusive rolling spring principle is the key to its performance that sets it apart from all other miniature switches. Millions of ACRO switches are in use on countless products from coin operated machines to aircraft and military equipment. Many variations can be furnished. Standard Model "M" Und. Labs. Insp. 10 Amps 125 Volts A.C. Coin Model "M" Und. Labs. Insp. 3 Amps 125 Volts A.C. Circuits: Single pole, double throw, normally open or normally closed.



MODEL 1-A

This original, basic ACRO enclosed switch is furnished with various types of actuators as shown at right. Some have been tested to over two hundred million actuations. Und. Labs. Insp. 10 Amps 125 Volts A.C., 5 Amps 250 Volts A.C.



No. 5L Leaf Actuator.

No. 2M Roller Leaf Actuator.

No. 48L Light pressure hinged leaf.

No. 63L Long travel, light pressure.

Write for details and give us any problem you may have.

THE ACRO ELECTRIC COMPANY

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form conductive coating of suitable electrical resistance on its surface. The surface of this coating is electrically conductive, and the ends C and D of the magnet make electrical contact with the pole pieces.

One then connects parts A and F to one terminal of a voltage source, and parts B and G to the other terminal, shown as ground in this case. A current I_0 passes through the magnet, the magnet acting as a potentiometer owing to the uniform distribution of resistance along its surface, and there is a linearly increasing potential from D to C. The distribution of electrical potential on the surfaces of the model is practically the same as that of magnetic potential on the corresponding surfaces of the magnetic circuit.

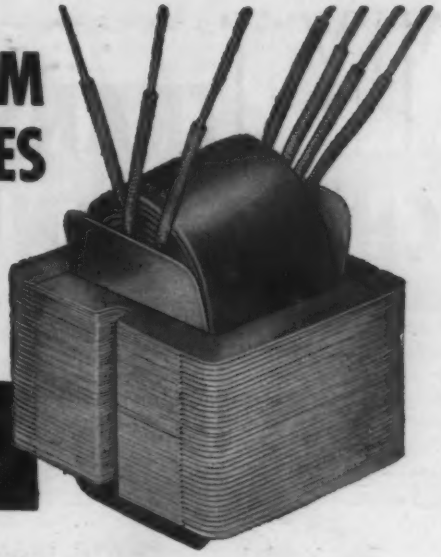
If the model is immersed in a tank containing, for example, a copper sulphate solution, a current I_1 passes from shim G to ground and a current I_2 passes from D to ground. These currents are measured by meters inserted as shown. The difference between I_2 and I_0 is proportional to the leakage fluxes, and I_1 is proportional to the useful flux. The factor F is then

$$F = \frac{I_1 + I_2 - I_0}{I_1}$$

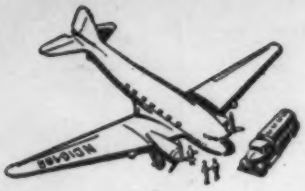
The accuracy of the method depends largely on the value of the factor f. The surfaces of each pole and corresponding shim in the model are equipotential ones, while the soft iron parts in the magnetic circuit may be considered approximately such only if the drop in magnetomotive force from the ends of the magnet to the pole faces carrying the useful flux is small. This error can be eliminated[3], but the complication of so doing seems excessive compared to the accuracy generally required in magnetic circuit design.

The change in linear distribution of the potential along the magnet by currents entering and leaving its surface when it is immersed is another source of error. However, experience indicates that if the original (unimmersed) current I_0 is about five times the total additional current due to leakages from and to the immersed magnet, the error is negligible. On the other hand, it is undesirable to make the current through the coating excessively large compared to the other

AIRCRAFT FUEL GAGE SYSTEM BEATS INSULATION DIFFICULTIES WITH *Varglas Silicone* SLEEVING



Minneapolis-Honeywell, Designer of Aviation's Best Remote Indicating System, Finds SILICONE Unequalled

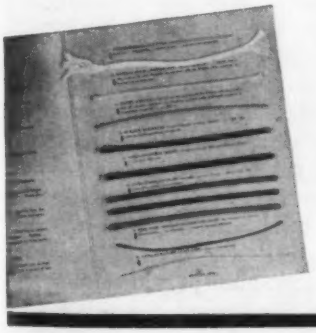


PRODUCING a remote-registering fuel indication system for the aviation industry — one that performs dependably and accurately throughout the temperature range facing modern aircraft, is undisturbed by position changes of the ship, and that offers no fire or mechanical hazard through being in contact with fuel supply — is an accomplishment of Minneapolis-Honeywell Regulator Company.

Briefly, the gage system works on the capacitance principle. The tank units are actually cylindrical condensers, mounted vertically in the tank, with concentric tubes forming the plates. The gasoline level is the same between the plates as in the tank, and the change in liquid level causes variation in the capacitance between the electrodes. A balancing potentiometer, in moving to equalize voltage between the tank unit and the fixed condenser, moves the pointer in the indicating head.

In choosing materials for best performance, Varglas SILICONE insulation was selected for protective sleeving on leads to the coils in the power unit. The well-known outstanding characteristics of SILICONE insulation explain its superb performance in this application.

Varglas SILICONE tubing provides, with no increase over standard wall thickness, dielectric values up to 7000 volts, through temperature range from 500°F to −85°F. SILICONE sleeving likewise retains its pliability, moisture and oil resistance, non-flaming nature, and mechanical strength (greatest of any accepted insulation material) through this temperature range.



If you have insulation difficulties that usual materials cannot handle, investigate Varglas SILICONE. Write for information and samples of SILICONE, as well as other Varflex Sleeving and Tubing. Let us work with you on special problems.

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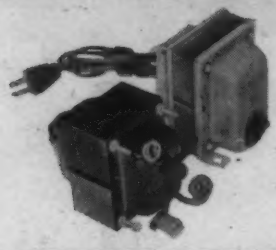

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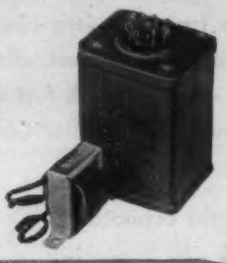

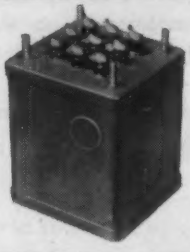

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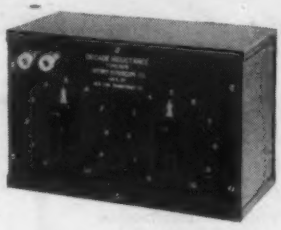

NEW YORK TRANSFORMER CO., INC.

GENERAL OFFICES: 39 CHAMBERS ST., NEW YORK 7, N. Y.—PLANT: ALPHA, NEW JERSEY

currents, because its value must be subtracted from the others.

Practical Details

To reduce polarization, alternating voltage is used. About two volts at power line frequency has proved satisfactory. The currents can be measured by a single meter providing that switching it between positions does not change the potential distributions.

The scale of the model is immaterial, but the model should be small compared to the tank. A separation from the outside surfaces of

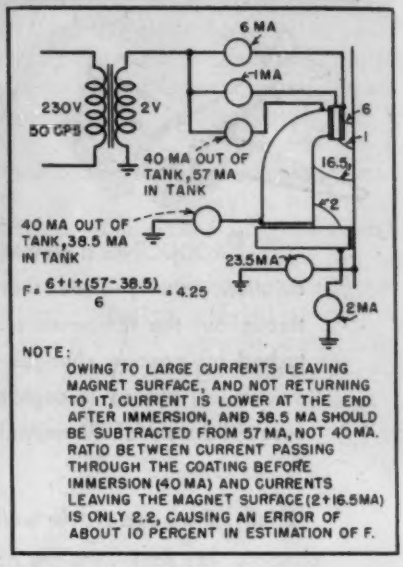
6 MA
1MA
230V
50 CPS
2V
6
1
40 MA OUT OF TANK, 57 MA IN TANK
16.5
2
40 MA OUT OF TANK, 38.5 MA IN TANK
23.5MA
F = 6+1+(57-38.5)/6 = 4.25
2MA
NOTE:
OWING TO LARGE CURRENTS LEAVING MAGNET SURFACE, AND NOT RETURNING TO IT, CURRENT IS LOWER AT THE END AFTER IMMERSION, AND 38.5 MA SHOULD BE SUBTRACTED FROM 57 MA, NOT 40 MA. RATIO BETWEEN CURRENT PASSING THROUGH THE COATING BEFORE IMMERSION (40 MA) AND CURRENTS LEAVING THE MAGNET SURFACE (2+16.5 MA) IS ONLY 2.2, CAUSING AN ERROR OF ABOUT 10 PERCENT IN ESTIMATION OF F.

FIG. 2—Measurement of a symmetrical magnet model to determine leakage fluxes

the model to the inside surfaces of the tank equal to about three times the overall dimensions of the model is a minimum. On the other hand, it has been found that, if there are small air gaps in the actual magnetic circuit, it is better to make a fairly large scale model. If any gap in the model is smaller than about 0.125 inch, voltage should be applied only for brief periods and the currents read as quickly as possible when the model is immersed. Although it is difficult to specify a suitable value of resistance for the coating to the magnet, about 100 ohms has been found satisfactory. The leakage to and from the magnet can be adjusted within limits by varying the concentration of copper sulphate between 0.001 and 0.01 normal to obtain the desired conditions.

Only one-half of a symmetrical circuit is necessary, the other half

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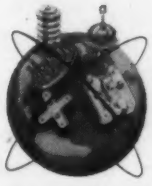
Extensive experience in the design and manufacture of a wide variety of ceramic parts gives the Stupakoff organization a fund of information that can be useful to you in reducing costs and improving performance. We will gladly place our knowledge at your disposal.



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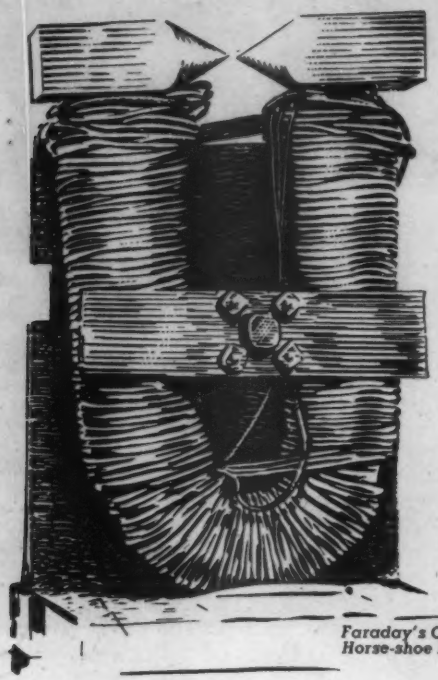

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For 30 years Coto-Coil has been winding coils which have helped make practical theories first demonstrated by Faraday 150 years ago. Our modern facilities and "know how" can provide the windings you need. We shall be glad to quote.

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being replaced by a conductive plate. Figure 2 shows a magnetic circuit that was tested in this way. The model was built so that an estimation of F and also of ratios of the fluxes entering and leaving the various soft iron parts and hence of f could be made.

The coating for the magnet presented difficulty, but Radio Corp., Pty. Ltd. (Australia) coated the models satisfactorily with the process used by them for manufacturing volume controls. A reasonably satisfactory coating may also be obtained by painting a wooden model with phenolic base lacquer and, while the surface is still wet, applying a fairly coarse bronze powder. The model is then baked in an oven until the lacquer is cured.

Although this electrolytic tank method for studying permanent magnet circuits has given fairly satisfactory results, it is still in the experimental stages. Extensive testing of the method and an easy, inexpensive means of constructing the model are needed. Although Dr. A. Edwards[3] has suggested the use of the electrolytic tank for estimating leakage flux in magnetic circuits, it is believed that the computation of F from simple measurements of currents has not heretofore been presented. The author acknowledges the helpful co-operation of T. P. Strickland, A. F. B. Nickson, and C. M. Gray.

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(1) E. M. Underhill, Permanent Magnet Design, ELECTRONICS, p 126, Dec. 1943, and Designing Stabilized Permanent Magnets, ELECTRONICS, p 118, Jan. 1944.

(2) S. Evershed, Permanent Magnets in Theory and Practice, *The Jour. of the Inst of Elec Engrs*, 58, p 780, 1920; 63, p 725, 1925.

(3) Discussion on a paper by D. J. Desmond, The Economic Utilization of Modern Permanent Magnets, *The Jour of the Inst of Elec Engrs*, Part II, 93, p 345.

(4) E. O. Willoughby, Some Applications of Field Plotting, *The Jour. of the Inst of Elect Engrs*, Part III 93, no. 24, p 288, July 1946.

SURVEY OF NEW TECHNIQUES

GLASS-METAL VACUUM SEALS of large diameter, and automatic cathode-ray tube assembly machinery developed by RCA engineers may make possible economical production of a 16-inch metal-walled kinescope having a 125 square inch picture area. It is believed that the

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ALTEC LANSING SCIENTISTS DISCLOSE BASIC IMPROVEMENTS IN HIGH QUALITY SOUND REPRODUCTION IN NEW SPEAKERS

NEW 603B MULTICELL DIA-CONE SPEAKER

The new 603B Multicell Dia-cone speaker is as superior to the original 603 Model as the 603 was superior to its competitors. The new 603B has a 30% larger Alnico V permanent magnet; massive circular magnetic circuit; almost 100% increase in acoustic efficiency (2.5 db increase over the 603).

SPECIFICATIONS

Angle of Horizontal Distribution	60°
Angle of Vertical Distribution	40°
Power Rating	25 watts
Voice Coil Impedance	8 ohms
Required Amplifier Output Impedance	6-10 ohms
Voice Coil Diameter	3"
Weight	18 lbs.
Speaker Diameter	15-3/16"
Depth	7"

← NEW MODEL 604B DUPLEX SPEAKER SHOWS REMARKABLE EFFICIENCY AND PERFORMANCE

Authorities on sound quality—the experts in the broadcasting, recording, and motion picture industries—who considered the previous Altec Lansing Duplex speaker (the 604) as the finest two-way speaker unit that science has produced, were literally thunderstruck when they listened to "previews" of the new improved Model 604B. Among outstanding new features are: 1,000 cycle crossover frequency using the new N-1000B network with adjustable high frequency control; an exclusive Altec Lansing development used with the high frequency metal diaphragm to smooth the frequency response beyond belief from 1,000 cycles to 16,000 cycles.

SPECIFICATIONS

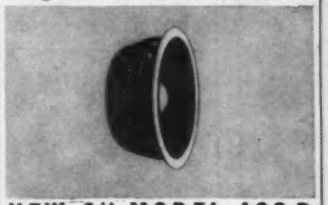
Angle of Horizontal Distribution	60°
Angle of Vertical Distribution	40°
Power Rating	30 watts
Network Impedance	16 ohms
Required Amplifier Output Impedance	8-16 ohms
Diameter	15-3/16"
Depth	11⅛"
Weight	40 lbs.

NEW MODEL 600B DIA-CONE SPEAKER

"Greater quality per dollar" describes the new low-priced high quality 600B Dia-cone speaker unit. Because of the high efficiency, small space requirements, light weight and superior quality of reproduction, the 600B is ideal for home use, sound reinforcement systems and industrial applications.

SPECIFICATIONS

Power Rating	20 watts
Voice Coil Impedance	8 ohms
Required Amplifier Output Impedance	6-10 ohms
Voice Coil Diameter	3"
Speaker Diameter	12¼"
Depth	5¼"
Weight	12 lbs.



NEW 8" MODEL 400B DIA-CONE SPEAKER

A low-priced high quality unit with a much higher efficiency than is found in ordinary 8" speakers: important in use with amplifier capable of delivering only from 5 or 6 watts. Exceptionally high power rating results from Altec Lansing design and use of a large Alnico V permanent magnet.

SPECIFICATIONS

Power Rating	12 watts
Voice Coil Impedance	8 ohms
Required Amplifier Output Impedance	4-8 ohms
Voice Coil Diameter	1¾"
Speaker Diameter	8¼"
Speaker Depth	3⅝"
Weight	4 lbs.

Altec Lansing Corporation, one of the world's largest makers of professional and theatre-type speaker systems, has announced a new, basically improved line of general purpose, high quality speakers. Altec scientists call attention to the fact that these new speakers,—constituting a complete new line—have been fundamentally re-engineered, and are the result of the application of new scientific discoveries resulting from intensive original research in Altec Lansing laboratories; they are *not*, it is emphasized, mere modifications or "reworking" of present models. The new line of speakers is offered "with the fullest conviction that never before has such a superb group of speakers been presented to a discriminating and quality-conscious public."

FREQUENCY RESPONSE CURVES PUBLISHED IN ILLUSTRATED BROCHURE

With the announcement of the new line of speakers, Altec Lansing announces that frequency response curves will be published on all its speakers. These curves are guaranteed to be accurate, dependable and true reproductions, made on production run speakers with equipment used by Motion Picture Research Council for establishing speaker system standards in the motion picture industry.

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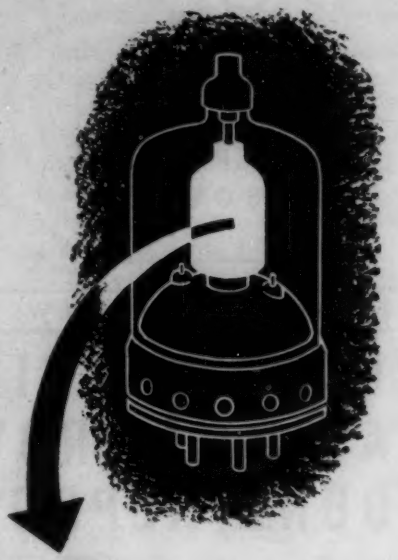
tube, using magnetic deflection, has a conventional base, glass neck around the electron gun, and glass face, but a metal flare. Using metal for the flare has three chief advantages over glass: the envelope is considerably lighter for the same strength, is conducting (without needing an Aquadag coating), and provides magnetic shielding. The 16-inch tube is only a few inches longer than 10-inch tubes. From the engineering test samples of this new construction that have been made, it appears that, after it has been in production for a few years, the cost will be comparable to the current price of 10-inch tubes. Part of the million-dollar expansion of the RCA Lancaster plant will provide facilities for its production. For television receiver designers, this tube offers a new technique for providing a screen size between the popular 10-inch directly viewed and the larger projected picture.

DETONATIONS are studied by recording light intensity and sound wave produced by the explosion. The pickup contains a photocell, protected by an opal glass screen, with its correction filter, a carbon microphone, associated calibration and control components, and cathode-follower output. A container of Silica-Gel prevents misting of the

Light and sound pickup is mounted on an antivibration chassis

window. The signals are fed to an Avimo (England) six-channel oscillograph using 1.5-inch cathode-ray tubes in mu-metal shields. The traces are reflected by mirrors to standard 70-mm perforated recording film or paper. A 15-channel



graphite anodes

give greater stability, longer life to tubes for electronic heating

Marketwise tube manufacturers, alert to new developments, are using Speer Graphite Anodes in the tubes they make for electronic heating equipment.

The only real low temperature anode, graphite gives tubes these better operating characteristics:

- *Higher safety factor when overloaded*
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Graphite anode tubes are equally well suited for diathermy work, or for almost any other power amplification assignment at any frequency, including VHF. Look for *graphite* anodes when you're looking for cooler, more efficient tube operation.

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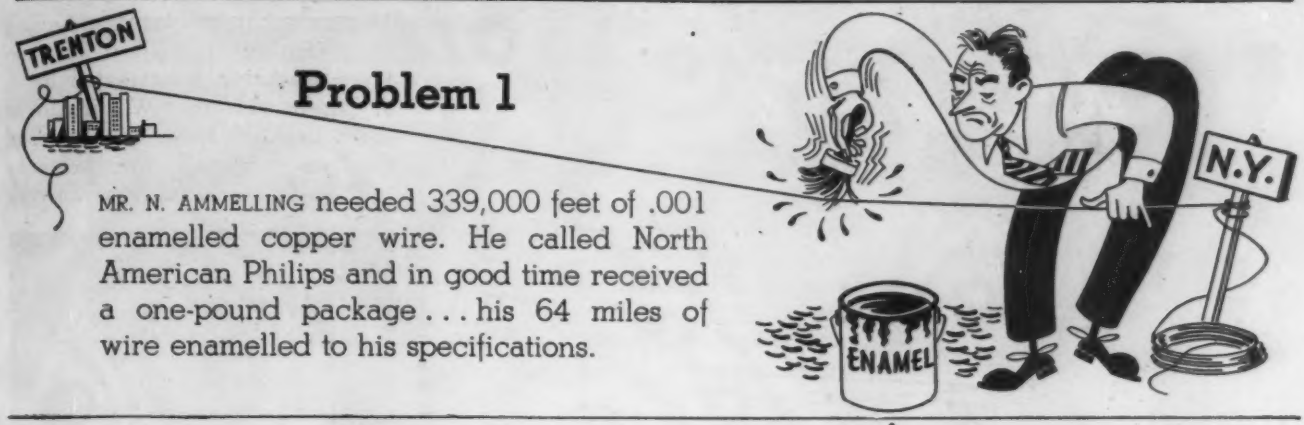

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Problem 2

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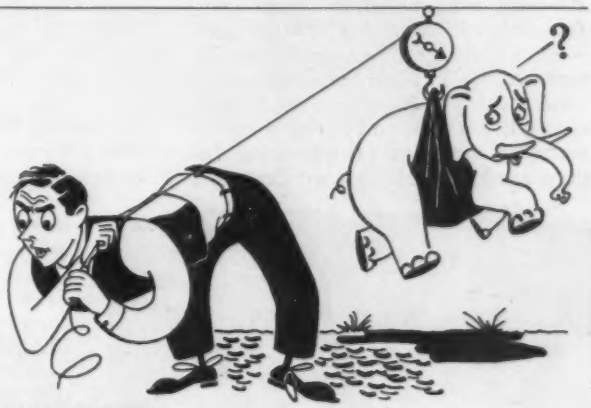
Problem 3

MR. E. LONG GATE wanted a quantity of Fine Wire to meet close specifications for tensile strength and elongation. Calling Fine Wire Headquarters, he soon received the order, filled to his exact specifications.



the answer

WHY not call Fine Wire Headquarters when you have a question about fine wire? We can't do the impossible, but we can do lots of things that can bring you the right fine wire for the job.

So—when you have a problem on Fine Wire, Tungsten or Molybdenum—wire, phone or write to North American Philips, makers of NORELCO Fine Wires, and ELMET Tungsten and Molybdenum products.

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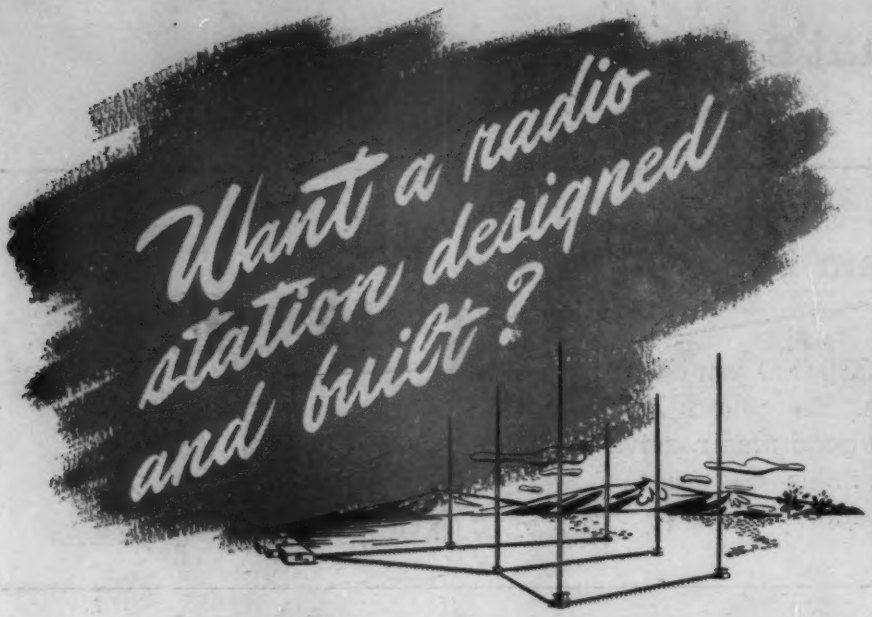


LET *Andrew* DO IT!

The Monona Broadcasting Company, Madison, Wisconsin, had the money but no station. Faced with "impossible" allocation difficulties, they called on Andrew engineers, who succeeded in finding a frequency and designing a directional antenna system. Thus, WKOW was born. Within ten months after the construction permit was granted, Andrew engineers completely designed, built, tuned, and proved performance of a six-tower 10 kw. station – an unusually difficult engineering feat accomplished in record-smashing time. A complete "package" of Andrew transmission line and antenna equipment was used, again emphasizing Andrew's unique qualifications: Complete engineering service with unsurpassed equipment.

Mr. Harry Packard, General Manager of WKOW, wrote:

"Speaking for the entire staff of WKOW, I would like to congratulate the Andrew Corporation on the remarkable engineering job it performed in helping us get WKOW on the air.

We feel that the technical perfection of our installation is due in great part to the efficiency of Andrew equipment and engineering service.

In particular we wish to thank Mr. Walt Kean of the Andrew Broadcast Consulting Division who was responsible for conceiving and designing the installation, supervising construction of all antenna equipment, and doing the final tuning and coverage surveys."

A total of 13,618 feet of Andrew transmission line and complete phasing, antenna tuning, phase sampling and tower lighting equipment went into this job, complementing the best in engineering with the ultimate in radio station equipment.

So, just write Andrew when you are ready to enter the broadcasting field. Andrew will get you on the air.

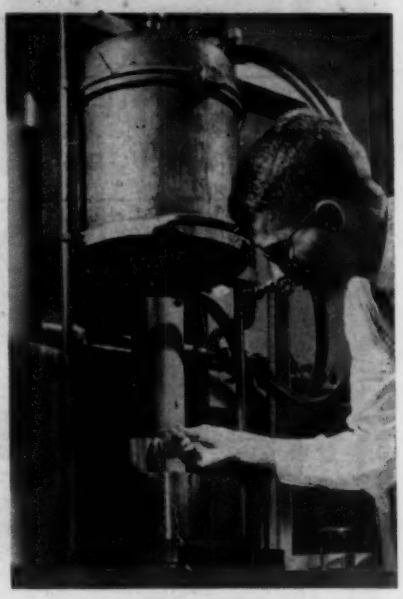
Andrew CORPORATION

363 EAST 75th STREET CHICAGO 19

TRANSMISSION LINES FOR AM, FM, TV • DIRECTIONAL ANTENNA EQUIPMENT • ANTENNA TUNING UNITS • TOWER LIGHTING EQUIPMENT • CONSULTING ENGINEERING SERVICE

oscillograph using the same principle can be used if more data is to be recorded.

ELECTRONIC TUBE MATERIALS having high melting or fusing temperatures are being investigated by J. J. Mason at the Westinghouse Lamp Research Lab. The powdered material is heated under pressure by high-frequency current flowing

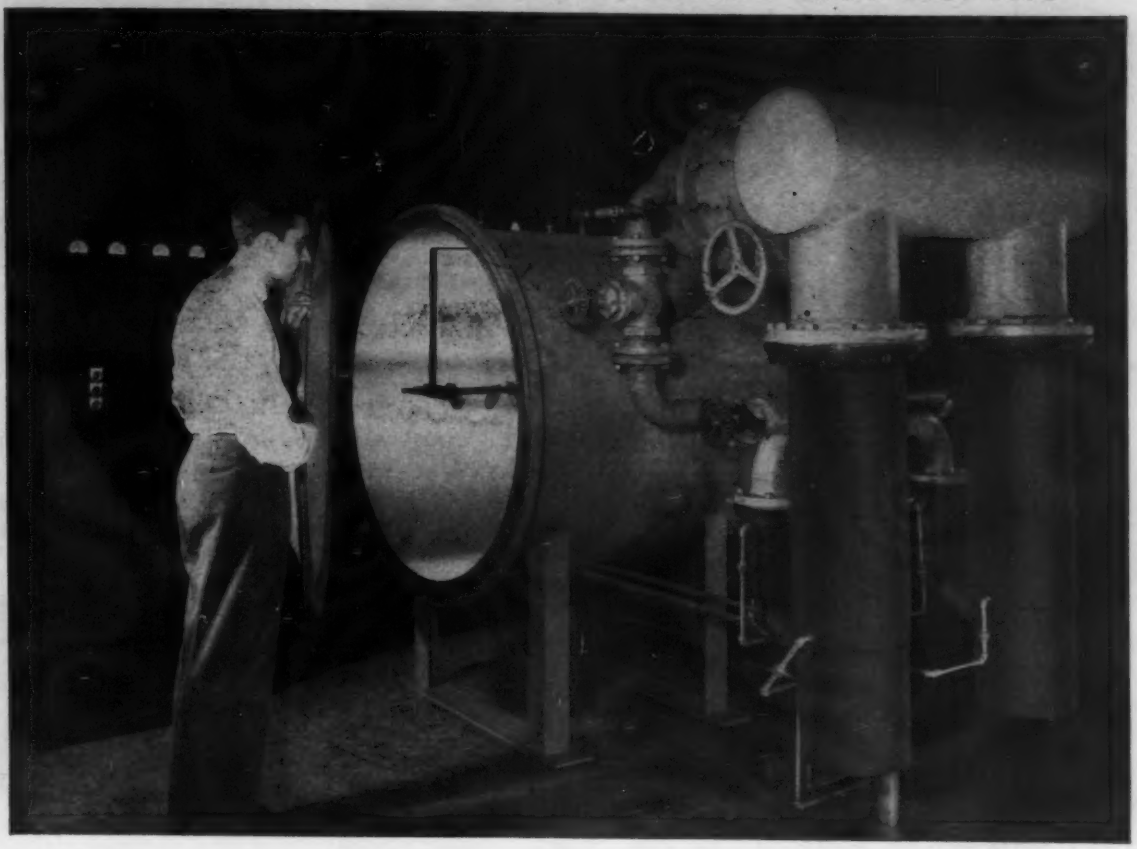


High melting point materials are fused in a high-temperature high-frequency furnace

in an applicator ring encircling the crucible in which it is contained. Tungsten is used for applicator coil and crucible because its melting point is higher than the 4,700 F to which the test materials are heated. The research is directed toward improving electronic tubes.

CERAMICS for use as dielectrics in capacitors were used in Germany. One such ceramic consisting of 95 parts by weight of titanium dioxide, 5 parts bentonite, and 2 parts tungsten trioxide has a dielectric constant of 90 to 95 and a power factor at one megacycle of 0.03 to 0.05. It was made into tubular and disc capacitors of 4, 8, and 12-mm diameter and 0.3, 0.4, and 0.6-mm wall thickness. The ceramic is metallized to form the capacitor. Inductors were also formed by metallizing ceramic bases (PB-81277, mimeograph $0.50; earlier OTS reports on the German ceramic practices are PB-6494 mimeograph $1.00, and PB-18776 mimeograph $3.75).

INDUSTRIAL HIGH VACUUM COATING UNIT NO. 3103



This High Vacuum Coating Unit is designed for low-cost production of evaporated films on glass and plastics.

The capacity of the stainless steel tank—48" diameter, 48" long—makes possible processing of large batches and large pieces on a production basis.

The pumping system has ample speed to handle the outgassing of plastics and consistently maintains rapid coating cycles.

For further details, write VACUUM ENGINEERING DIVISION, National Research Corporation, Boston 15, Massachusetts.

HIGH VACUUM FOR INDUSTRY

NATIONAL RESEARCH CORPORATION

Vacuum ENGINEERING DIVISION

"FREEZING"
is expensive

WHERE BASIC DESIGNS IN ELECTRIC CONTROLS ARE RESULT-ENGINEERED FOR YOU

Unique design and spring suspension prevent it in this Ward Leonard Relay

The generous wipe imparted to the contacts of Ward Leonard Heavy Duty (105) Relay by its unique design and spring suspension, results in freedom from contact "freezing" or welding.

This mighty midget will perform motor starting functions ordinarily assigned to larger relays.

Ward Leonard relays are "Result-Engineered". By modifying a basic design, Ward Leonard can give you the results of a special . . . for the price of a standard.

Write for Relay Catalog. Ward Leonard Electric Co., 31 South St., Mount Vernon, N. Y. Offices in principal cities of U. S. and Canada.

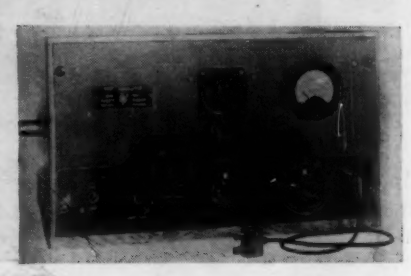
WARD LEONARD
ELECTRIC COMPANY
RESISTORS · RHEOSTATS · RELAYS · CONTROL DEVICES

NEW PRODUCTS
(continued from p 144)

clutch mechanism. Sound in the microphone starts the recorder which maintains operation for about 5 seconds after the cessation of sound. It is fully described in catalog 4901.

Test Oscillator

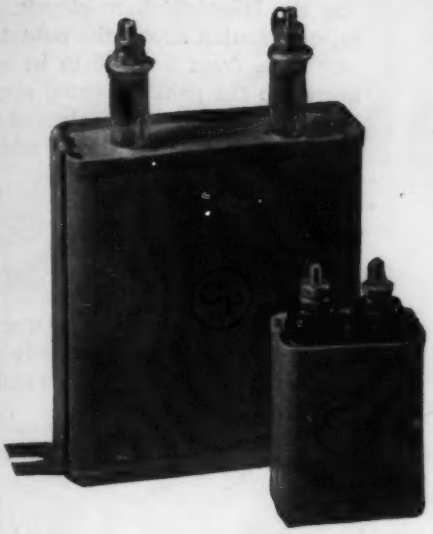
HEWLETT-PACKARD Co., 395 Page Mill Rd., Palo Alto, Calif. Model 650A resistance tuned oscillator has an output which is flat within 1 db from 10 cycles to 10 mc. Voltage



range is 0.00003 to 3 volts. Output impedance is 600 ohms, but a 6-ohm impedance may be had through an output voltage divider supplied with the instrument.

Scaler

TRACERLAB, INC., 55 Oliver St., Boston 10, Mass. Type 64 scaler for radioactivity measurements uses Duoscale plug-in units incorporat-



PLASTICON
Plastic Film Oil-Filled
CAPACITORS—

1. More Economical

2. Smaller—Lighter

3. Better Electrical Characteristics

1. MORE ECONOMICAL

MFD.	VOLTS DC	List Price PAPER CAPACITOR	List Price PLASTICON AOC	SAVING
10	1000	$15.18	$10.67	$4.51
4	2000	13.67	9.24	4.43
2	3000	22.78	15.40	7.38
1	4000	33.54	27.50	6.04
2	5000	48.73	41.25	7.48
Above are typical examples.				

PLASTICONS are the result of technological advances . . . cost less to manufacture, give better performance.

2. SMALLER—LIGHTER

MFD.	VOLTS DC	Approx. Weight		Approx. Cubic Dimensions	
		PAPER CAPACITORS	PLASTICONS	PAPER CAPACITORS	PLASTICONS
10	1000	1.95 lbs.	1.7 lbs.	31 cu. in.	30 cu. in.
4	2000	2.0	1.23	31	23
2	3000	2.0	1.21	31	19
1	4000	1.77	.94	28	19
2	5000	5.2	2.9	70	60

3. BETTER ELECTRICAL CHARACTERISTICS

	Paper Capacitors	Plasticons
Power Factor at 85°C 60 cycles	0.7%	0.3%
Resistance at 85°C megohms per Mfd.	40	100
Capacitance/Temp. Coefficient 100% at 25°	−40°C=73% +85°C=97%	−40°C=94% +85°C=103%

PLASTICON CAPACITORS given are Type AOC, mineral oil-filled.
PLASTICON ASC silicone-filled have better characteristics.
Paper Capacitors given are chlorinated diphenyl impregnated.

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MANUFACTURERS of GLASSMIKE CAPACITORS and HIGH VOLTAGE POWER SUPPLIES.

HERE is a bird that can talk. But does that make him smart? Not at all.

For example — when he asks for a cracker, does he specify what kind of a cracker — what flavor, what make? No! And that makes him a dumb bird. There are hundreds of kinds of crackers, from Saltines to Pilots, and he certainly must like some one kind best. Does he ask for it? Never! He just says "Cracker".

To get what you want, you have to be specific. That applies to lots of things, including crackers and Mica. When you want the best Mica, specify MACALLEN Mica. That means more than just the product — it also means the service back of the product — capacity, experience, policy, responsibility — all of these things are expressed in the word MACALLEN. Say it, write it into specifications and on requisitions.

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ALL FORMS, ALL QUANTITIES — ALL DEPENDABLE

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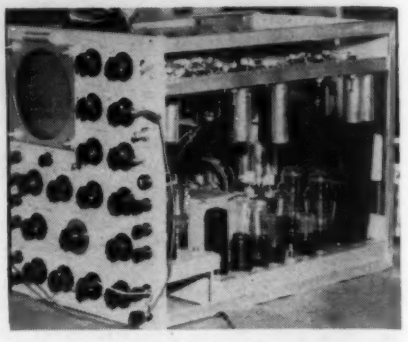
THE MACALLEN COMPANY • 16 MACALLEN ST., BOSTON 27, MASS.

CHICAGO: 565 W. WASHINGTON BLVD. • CLEVELAND: 1231 SUPERIOR AVE.

ing the Higginbotham circuit. A selector switch allows the output of any scale from 8 to 64 to be connected to the panel-mounted counting register. Resolving time of the scaling unit is better than 5 microseconds.

Oscilloscope

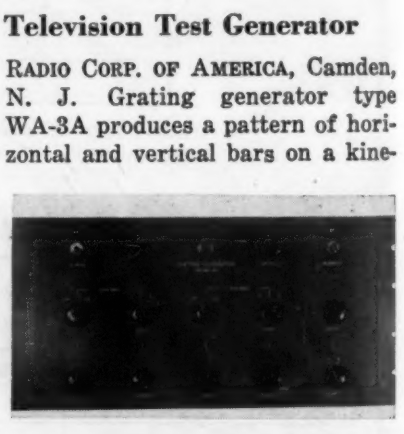
TEKTRONIX, INC., Portland, Oregon. The Vollum portable cathode-ray oscilloscope weighs 65 pounds and is



capable of observing frequencies as high as 10 megacycles. In use by a number of research laboratories, the instrument is inexpensive.

Television Test Generator

RADIO CORP. OF AMERICA, Camden, N. J. Grating generator type WA-3A produces a pattern of horizontal and vertical bars on a kine-



scope screen to aid in determining correct linearity alignment of deflection circuits for picture and camera tubes. Polarity of the blanking signal can be changed to permit use of the generator in any video system.

Radiation Indicator

INSTRUMENT DEVELOPMENT LABORATORIES, 229 W. Erie St., Chicago 10, Ill. Model 3360 pocket dosi-

"IT'S THE BEST YET!"

Yes! We think it's the best yet. We think this transmitter ideal for such applications as Police, Forestry, Airport Traffic Control, Oil Fields, Aerophare, Beacons, Explorations, Public Utilities, Mining, Emergencies and Point-to-Point requirements. It can be controlled either locally or from remote position; either for telephone (A-3) or telegraph (A-1 or A-2) service . . . it is compact, complete and designed for hard service.

Other Equipment made and designed by Aero-com: Models VH-50 and VH-200 transmitters, operating range, 118-165 Mcs. (crystal controlled), power 50 and 200 Watts respectively; Model 12ACX-2A, 1 Kw. dual channel radio telegraph transmitter for medium and high frequencies (1.6 to 24 Mcs.); Model GM-8 modulator when used with above provides full modulation with a 750 Watt carrier. Complete Engineering data on Request.

Model 50HXS

Radiotelegraph or telephone Transmitter output 75 Watts (A-1); 50 Watts (A-2 or A-3) Frequencies 200-500 Kcs. and 1.6-13.5 Mcs. using plug in coils and crystals. A complete compact self-contained unit.

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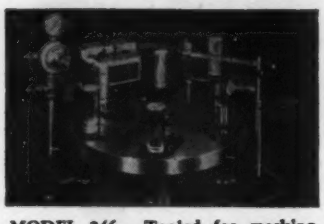
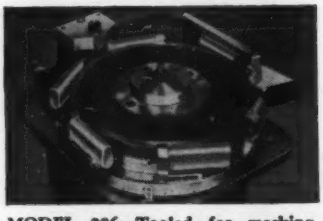
with NOBLEWEST

PRODUCTION MARKING MACHINES



MODEL 246—Tooled for marking on aluminum condenser parts. Production speed 60 to 70 pieces per minute.



MODEL 286—Tooled for marking capacitors. The complete inscription is permanently *rolled in*, lasts as long as product itself.

Don't let obsolete marking methods or equipment slow down your operations when production is the one big hope of lowering costs. The new Noblewest production marking machines, such as Model 157 (illustrated) have been developed especially to meet industry's demand for higher marking speeds and lowest cost per unit marked. Leading manufacturers of electronic products and their component parts are saving time and money every day with these superior marking machines. Whatever you make—in metal, plastic, hard rubber, etc.—chances are you too can mark it faster, better, cheaper with Noblewest. There's no obligation to find out. Just write Noble & Westbrook Manufacturing Co., 27 Westbrook Street, East Hartford 8, Conn.

MARK IT BEST WITH NOBLEWEST IMPROVED MARKING DEVICES

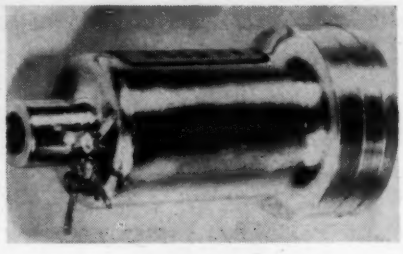
NOBLEWEST

EQUIPMENT FOR MARKING · GRADUATING · EMBOSSING · NUMBERING

meter indicates the amount of radio-activity in milliroentgens, to which the carrier of the instrument has been exposed. It is read by looking through a cupped eyepiece toward a light source.

Pressure Transducer

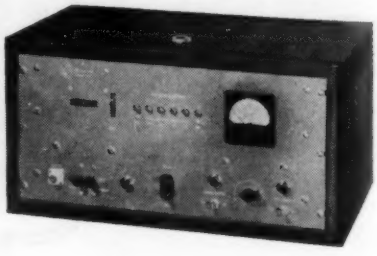
G. M. GIANNINI & CO., INC., 285 West Colorado St., Pasadena 1, Calif. Type 4713 pressure transducer operates in the range of plus or minus 20 inches of water. A



bellows is connected by mechanical means to a potentiometer such that large voltage variations are encountered for extremely small changes in pressure. The device weighs less than 3 ounces.

Radioactivity Scaler

INSTRUMENT DEVELOPMENT LABS., 223 West Erie St., Chicago 10, Ill. Model 165 scaler operates on impulses from a Geiger-Mueller counter which actuates a built-in register once for each 64 impulses



DPi

HIGH VACUUM RESEARCH AND ENGINEERING

Better Tubes—Longer Life—Increased Production through

DPI HIGH-VACUUM ENGINEERING

YOUR present rotary exhaust machines can be completely automatic in operation, yielding increased production for any size tube.

Converted to DPI vacuum equipment, your machines will have a *fractionating* oil diffusion pump and a small mechanical pump *under each separate port*. Tubes are rough pumped through automatic solenoid valves.

Protective devices with automatic controls will seal off the pumps and isolate the trouble in case of faulty tubes. Seal-off pressure will reach 5 x 10^{-6} mm of mercury *before* getter is flashed.

DPI-engineered rotary exhaust machines produce *cleaner* tubes *faster*, by continuous pumping throughout the cycle—eliminate large backing pumps and rotary slide valve.

For full information, write—

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Manufacturers of Molecular Stills and High-Vacuum Equipment; Distillers of Oil-Soluble Vitamins and Other Concentrates for Science and Industry

*Permanent Magnets do it Better in...

Kitchen Utensils

The SWING-A-WAY Can Opener with Automatic (Magnetic) Lid-lifter

TO make a safer, more sanitary can opener, Steel Products Mfg. Co., of St. Louis, required a device which would hold the lid after it was cut away from the can. On old-fashioned can openers, the lid might contaminate the contents of the can, or cut the fingers of the operator.

A permanent magnet solved this problem, simply, economically, efficiently. Our engineers designed this magnet—see illustration. It transmits its energy to a small frame which grips the can top and holds it until operator is ready to dispose of it. The resultant design produced many production and sales advantages.

Permanent magnets may develop unexpected savings and increased efficiency in your product. The Indiana Steel Products Company offers you an exceptional permanent magnet design service. Write for complete information.

ISP

THE INDIANA STEEL PRODUCTS COMPANY

PRODUCERS OF "PACKAGED ENERGY"
6 NORTH MICHIGAN AVENUE • CHICAGO 2, ILL.
SPECIALISTS IN PERMANENT MAGNETS SINCE 1910

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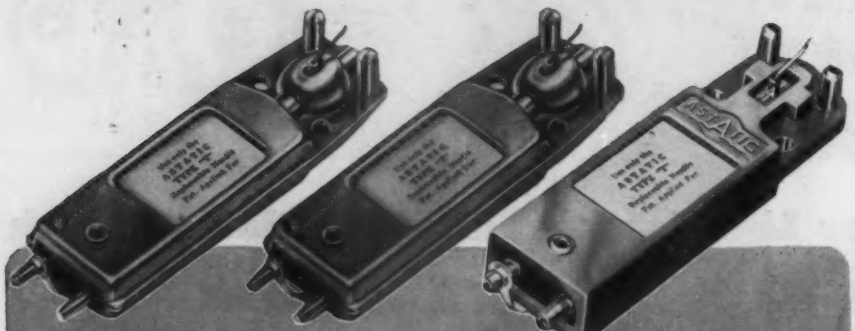
Incorporate the Advantages of "LT" CARTRIDGES in New Phonograph Engineering



Model "LT3-M" Stamped Aluminum Wgt. 11 Grams

Model "LT2-M" Stamped Steel Wgt. 20 Grams

Model "LT1-M" Die Cast Housing Wgt. 28 Grams

LOW NEEDLE TALK, Low Needle Pressure and Low Price combine to make Astatic's new "LT" Series Cartridges particularly desirable for new installations in all types of automatic record changers and manually operated phonographs. Now available with stamped steel and aluminum as well as die cast housings, "LT" Cartridges may be selected in the proper weight to provide optimum needle pressure and pickup inertia characteristics with various types of arms.

The response of these cartridges is exceptionally smooth over the entire frequency range from 50 to 10,000 c.p.s., with a gradual roll-off commencing at approximately 4,000 c.p.s. Minimum Needle Pressure, ¾ oz. Output Voltage, 1.0 Volt average at 1,000 c.p.s.

All models in the "LT" Cartridge employ Astatic's replaceable, Type "T" stainless steel Needle with electroformed precious metal tip.

Also highly recommended is Astatic's de luxe "QT" Series (Quiet Talk) Cartridge, employing a matched, replaceable Type "Q" Needle with sapphire or precious metal tip.

Literature is Available

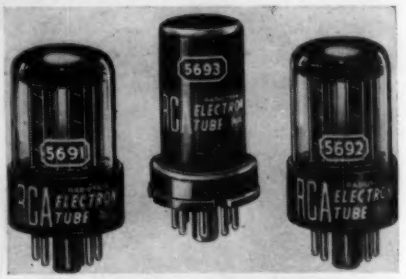
THE Astatic CORPORATION
ASTATIC CONNEAUT, OHIO
IN CANADA: CANADIAN ASTATIC LTD., TORONTO, ONTARIO

Astatic Crystal Devices Manufactured under Brush Development Co. patents.

received. A high-voltage supply of either 1,500 or 2,500 volts is provided. The internal circuit has an input sensitivity of 0.25 volt and resolving time is better than 5 microseconds. Electronic regulation is provided for the high-voltage supply so that the scaler will operate satisfactorily on line voltages from 95 to 130 volts.

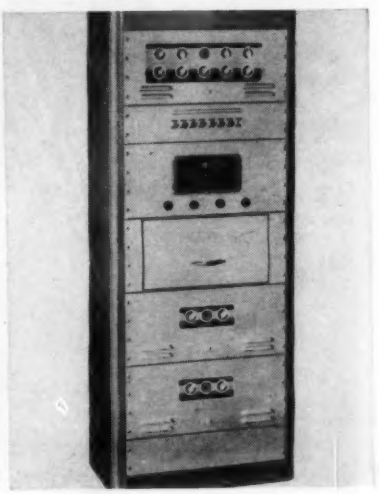
Small Industrial Tubes

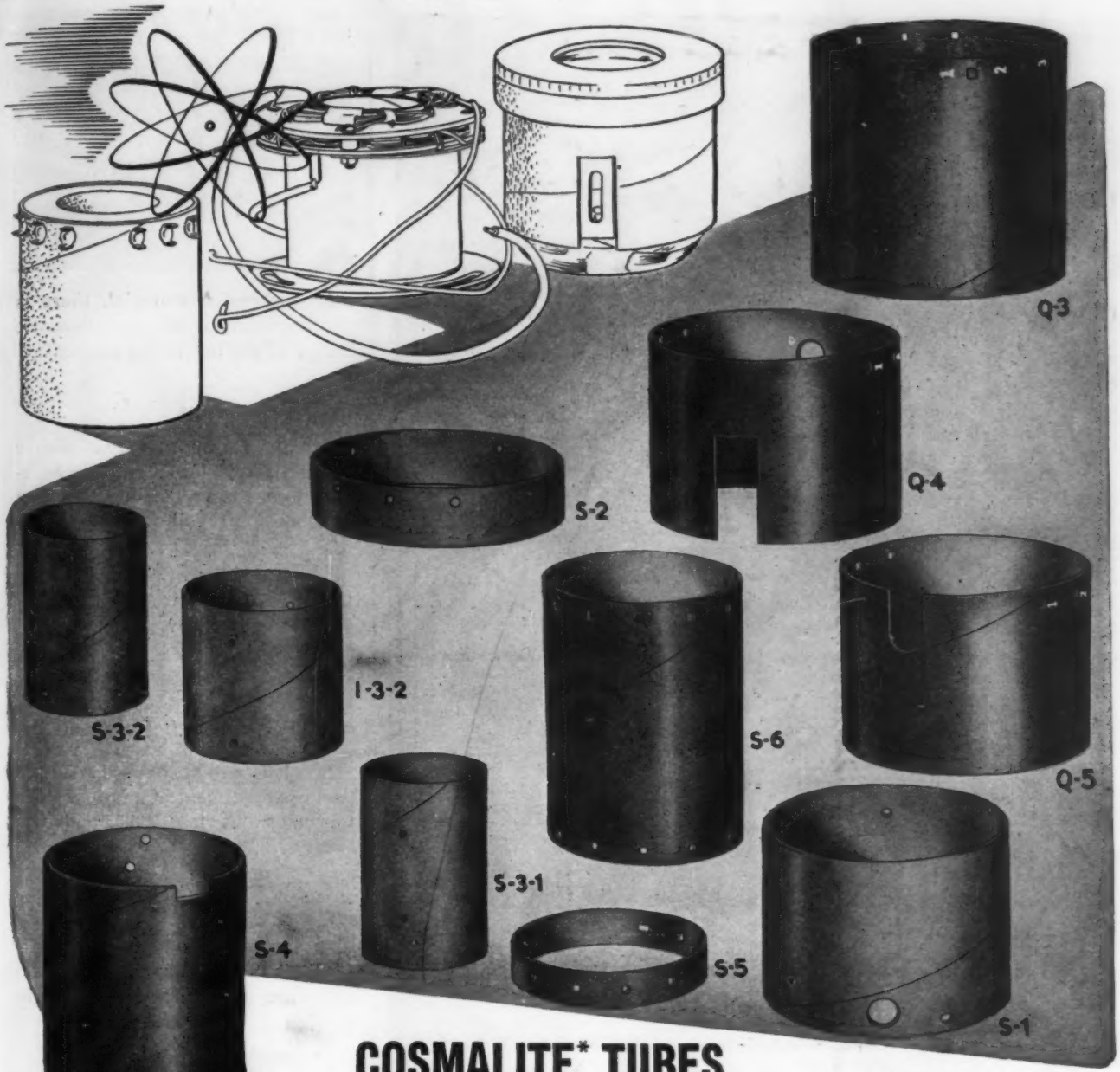
RADIO CORP. OF AMERICA, Harrison, N. J. The Special Red line of small tubes was specifically developed for critical industrial applications. First of the line which are identified by red bases for glass types and red envelopes for metal types are the 5691, a high-mu triode; the 5692, a medium-mu twin triode; and the 5693, a sharp cutoff pentode. Minimum life specification is 10,000 hours. A complete description is given in booklet RSB-1000.



Audio Rack Assembly

NEWCOMB AUDIO PRODUCTS Co., 6824 Lexington Ave., Hollywood 38, Calif. Model 595 cabinet illustrated





COSMALITE* TUBES

for *Television* deflection yokes

● These spirally laminated paper base, Phenolic Tubes are obtainable in sizes and with punching and notching that meet each customer's individual needs.
Quality performance at prices that appeal.

Other Cosmalite Types include...

#96 Cosmalite for coil forms in all standard broadcast receiving sets.

SLF Cosmalite for Permeability Tuners.

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Spirally wound kraft and fish paper Coil Forms and Condenser Tubes.
Inquiries given specialized attention.

DEFLECTION YOKE SHELLS	Inside Diameter	Length
S-1	3"	$2\frac{5}{16}$"
S-4	$2\frac{3}{8}$"	$3\frac{7}{16}$"
Q-3	3"	$2\frac{31}{32}$"
Q-4	3"	$2\frac{11}{32}$"
Q-5	3"	$2\frac{11}{32}$"
S-6	$2\frac{3}{8}$"	$3\frac{7}{16}$"
DEFLECTION YOKE CORES		
S-3-1	$1\frac{33}{64}$"	$2\frac{15}{32}$"
S-3-2	$1\frac{33}{64}$"	$2\frac{11}{32}$"
S-3-3	$1\frac{33}{64}$"	$2\frac{15}{32}$"
I-3-1	$1\frac{17}{32}$"	$2\frac{3}{8}$"
I-3-2	$1\frac{7}{8}$"	2"
DEFLECTION YOKE RINGS		
S-2	3"	$\frac{3}{4}$"
S-5	$2\frac{3}{8}$"	$1\frac{5}{32}$"

See our Exhibit #220 at the I. R. E. Radio Engineering Show

*Trade Mark Registered

The CLEVELAND CONTAINER Co.
6201 BARBERTON AVE. CLEVELAND 2, OHIO
- All-Fibre Cans • Combination Metal and Paper Cans
- Spirally Wound Tubes and Cores for all Purposes
- Plastic and Combination Paper and Plastic Items

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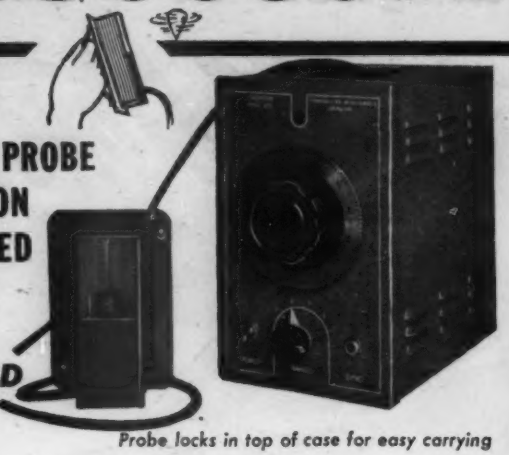
PRODUCTION PLANTS also at Plymouth, Wisc., Ogdensburg, N.Y., Chicago, Ill., Detroit, Mich., Jamesburg, N.J.
PLASTICS DIVISION at Plymouth, Wisc. • ABRASIVE DIVISION at Cleveland, Ohio
SALES OFFICES: Room 5632, Grand Central Term. Bldg., New York 17, N.Y., also 647 Main St., Hartford, Conn.
CANADIAN PLANT: The Cleveland Container Canada, Ltd., Prescott, Ontario

CML's New and Improved model 1210B

STROBOSCOPE



- UNIQUE HANDY PROBE
- "STOPS" MOTION
- MEASURES SPEED
- REVEALS VIBRATION
- LOW PRICED

Probe locks in top of case for easy carrying

This conveniently "handy" and inexpensive instrument enables the user to check speeds or study rotary or reciprocating motion. Vibrations and other undesirable motions can be quickly detected in the laboratory or factory. Covers 480 to 60,000 RPMs (or 8 to 1000 CPS) in four ranges using a one-to-one flashing rate. Lower or higher speeds can be determined using sub-multiple or multiple ratios. Frequency reading is accurate to better than 1%. Studies and tests can be made on uniform or variable speeds. Because of the unique design of the 1210B Stroboscope and small size of the Probe it has great flexibility of application and operation in crowded places. Price $115.00.

Please send for descriptive bulletin

Another CML-designed Electronic Tool

REGULATED

POWER SUPPLY

Model 1115

Developed to provide the three commonly used supply voltages in an unusually compact unit, CML Model 1115 Power Supply has found wide acceptance. Plate, bias and heater voltages and their controls are conveniently available for functioning in the lab or factory test position.

150-300 volts 70 mils. regulated
0-50 neg. bias 1 mil.
6.3 v. 3 amp. unregulated
Price f.o.b. N. Y. C. $89.95

CML —makers of the ROTOBRIDGE *Automatic Circuit Inspector*

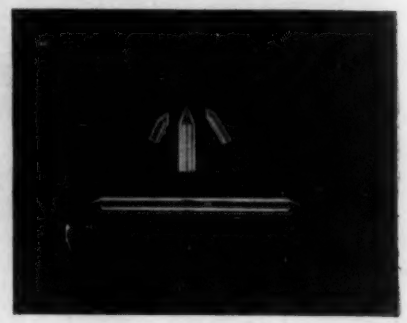
COMMUNICATION MEASUREMENTS LABORATORY, INC.

120 Greenwich Street • New York 6, N. Y. • Cable: COMUNILAB, New York

is designed for use with audio components such as preamplifier, switching panel, f-m receiver, drawer-type phonograph changer, and two high-power amplifiers. The equipment is fully described in specification sheet R-117.

Precision Pivots

SPRINGFIELD INSTRUMENT BEARING Co., 905 N. MacArthur Blvd., Springfield, Ill. Virtually friction-



less pivots are available for fine instrument bearings in sizes below ⅛ inch diameter.

Audio Oscillator

BARKER & WILLIAMSON, INC., 237 Fairfield Ave., Upper Darby, Pa. Model 200 audio oscillator uses a

modified Wienbridge RC oscillator. Designed for distortion or frequency measurements the unit covers the frequency range between 30 and 30,000 cycles. A bulletin is available describing this and other audio units.

Striped Wire

WILLIAM BRAND & Co., 276 Fourth Ave., New York 10, N. Y. A unique extrusion process allows color coding of plastic tubing or plastic insulated wire. Since the striping compound is identical with the

Fishing reel gears must operate smoothly at a speed of 3000 revolutions per minute or more, when a cast is executed. These gears must also withstand the strain of hauling in a fighting fish of unpredictable size and strength, thus rendering a dual purpose: speed and velvety smoothness in one direction—strength and durability in the other.

Instruments and machines have individual gear problems. For over a quarter of a century, Quaker City Gear Works has solved thousands of them and produced millions of gears of every description up to 60" in diameter for manufacturers in many diversified industries.

Aircraft controls, dental drills, electric clocks, gauges, indicators, heat controls, machine tools, radar, radios, washing machines and motion picture projectors are but a few of the many conveniences of modern progress which depend upon the heartbeat of Quaker City Gears. Your gear problem is our business, our large productive capacity is at your service.

YOUR INQUIRIES WILL RECEIVE PROMPT ATTENTION

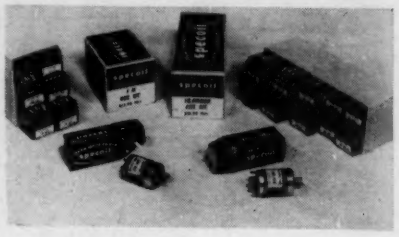
The heart of the Outdoorsman *Castomatic reel illustrated above is but one of many gear trains developed by our engineers and produced in our fully equipped plant.*

Quaker City Gear Works
INCORPORATED
1910 N. Front Street, Philadelphia 22, Pa.

other extrusion material, there is no impairment of the dielectric factor of the insulating tubing.

F-M Television Coils

SPECIAL PRODUCTS CO., Silver Spring, Maryland. Complete Specoil kits are avalable for either f-m or television sound and video chan-



nels. They are slug tuned with the tuning adjustment at the top. The television kit is $19.95 and f-m tuner is $12.95.

Antistatic Powder

GENERAL CEMENT MFG. CO., Rockford, Ill. For improved auto radio reception an antistatic powder is

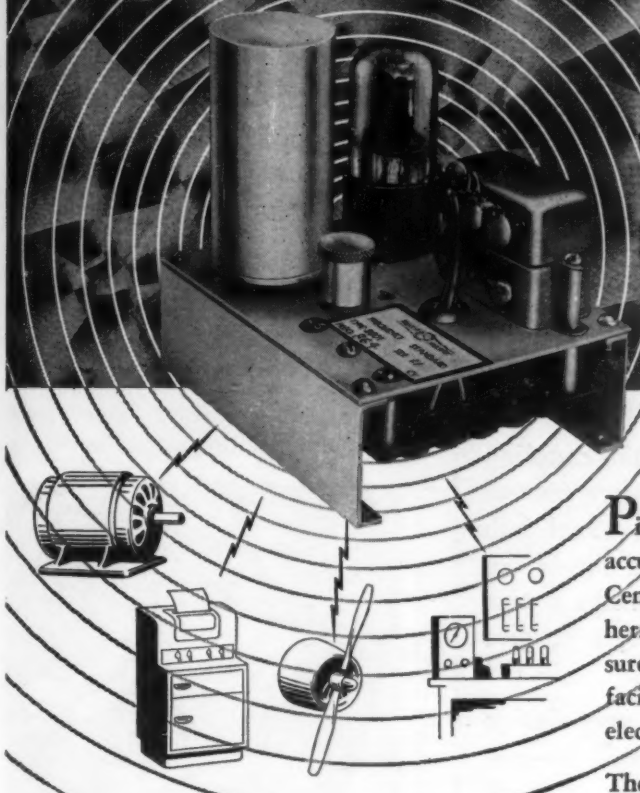
available that is especially helpful in synthetic tires. A special injector lists at $1.50 and sufficient powder for 5 tires costs $1.00.

Precision Resistors

SHALLCROSS MFG. CO., Collingdale, Pa. Type 136 resistors have maximum wattage, rating of 25 watts and maximum resistance of 150,-

PICK A NUMBER

ANY FREQUENCY FROM 40 TO 1,000



Pictured here is a tuning-fork frequency standard with accuracy guaranteed to one part per million per degree Centigrade. The fork is temperature-compensated and hermetically sealed against variations of barometric pressure. This standard, when combined with basic equipment, facilitates accurate speed and time control by mechanical, electrical, acoustical or optical means.

The unit is available separately or in conjunction with complete timing instruments. Our engineers are ready to cooperate on any problem.

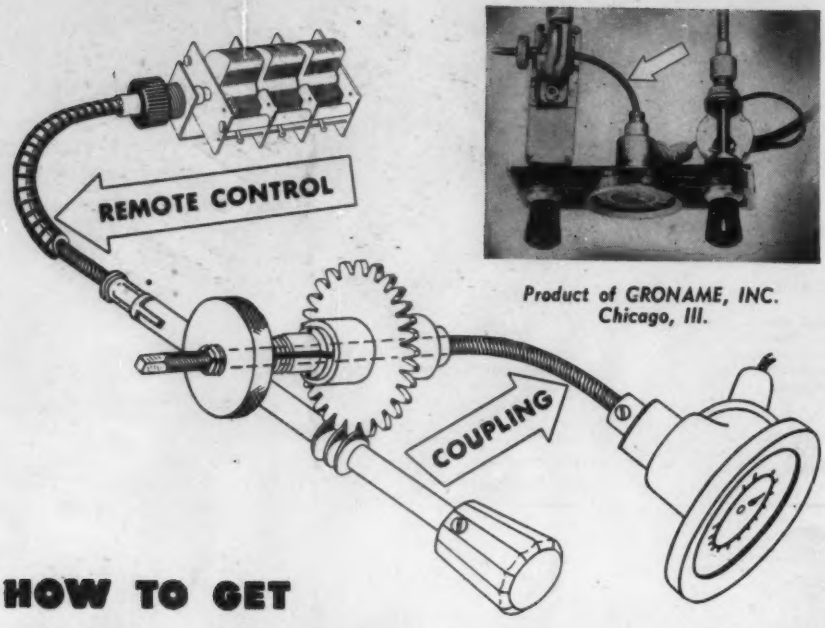
MOTORS • FACSIMILE • AIRCRAFT • LABORATORIES

American Time Products, Inc.

580 Fifth Avenue New York 19, N. Y.

[illegible] OF THE WESTERN ELECTRIC COMPANY

Simplify WITH S.S.WHITE FLEXIBLE SHAFTS



Product of GRONAME, INC.
Chicago, Ill.

HOW TO GET
"DUAL CONTROL" FROM ONE KNOB

The illustrations above show the ingenious way in which this was done on an automobile radio with S.S.White flexible shafts.

Note the method used to connect the coupling shaft to the worm gearing on the remote control shaft. It passes through the worm wheel hub and is clamped by a split collet on the end of the hub as shown in the sketch. This permits a nice adjustment of the coupling shaft length to give smooth, free operation.

You may find this idea useful in your design work. If you want to know more about it—and about many other design-simplifying uses of flexible shafts—

SEND FOR THE FLEXIBLE SHAFT HANDBOOK

This 260-page book gives facts and full engineering data about flexible shafts and how to select and apply them. A copy sent free, if you write for it on your business letterhead and mention your position.

S.S.WHITE INDUSTRIAL DIVISION
THE S. S. WHITE DENTAL MFG. CO. DEPT. E 10 EAST 40th ST., NEW YORK 16, N. Y.
FLEXIBLE SHAFTS • FLEXIBLE SHAFT TOOLS • AIRCRAFT ACCESSORIES
SMALL CUTTING AND GRINDING TOOLS • SPECIAL FORMULA RUBBERS
MOLDED RESISTORS • PLASTIC SPECIALTIES • CONTRACT PLASTICS MOLDING

One of America's AAAA Industrial Enterprises

000 ohms. Standard tolerance is 1 percent. Other multisection units are also available. Windings are noninductive.

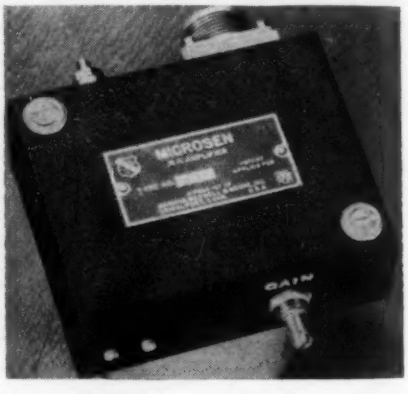
Rear Seat Speaker

VAN DRUFF SPECIALTIES, 8695 State St., South Gate, Calif. The rear-seat speaker illustrated uses a heavy-duty permanent magnet

speaker behind a special plastic grille. It will fit any car regardless of the contour of the package tray.

Telemetering Amplifier

MANNING, MAXWELL & MOORE, INC., Bridgeport 2, Conn. Model 143-AT2, the d-c amplifier for low level signals in telemetering, uses the



Microsen Balance principle. Maximum input voltage is 0.2 volt with an output of 0 to 5 volts. The unit has a time constant of 0.02 second. Power required is 5 watts.

Servotesting Scope

AMERICAN BRITISH TECHNOLOGY, INC., 57 Park Ave., New York 16, N. Y., distributors for Furzehill Laboratories, Boreham Wood,

ANOTHER NEW INSTRUMENT
JUST RELEASED

THE MEGA-MARKER SR.

THE ONLY 13 CHANNEL *CRYSTAL-CONTROLLED* MARKER OSCILLATOR for Rapid, Accurate Alignment of Television Receivers

FEATURES:—

*** CRYSTAL ACCURACY 0.01%**

*** SINGLE DIAL OPERATION**

*** PROVIDES SOUND CARRIER FREQUENCIES**

The MEGA-MARKER SR. is a newly developed electronic instrument for the generation of marker frequencies. *Provides* a precise source of frequencies throughout the televisions spectrum for all thirteen television channels. Each of these frequencies is controlled by a crystal whose accuracy is 0.01%. Such accuracy is more than adequate for all needs of television.

MEGA-MARKER SR. can also be used alone for the alignment of the local oscillator for all thirteen channels. This is accomplished by using the sound channel to furnish an indication of discriminator output.

The single-dial control gives a rapid and efficient means of frequency selection without the necessity of consulting charts or calibration curves.

The MEGA-MARKER SR. facilitates the alignment of the r.f. channels in the same manner that the MEGA-PIPPER and MEGA MARKER facilitate the i.f. alignment.

MISC.: 117 volt 60 cycle Size 8 x 16 x 8 Weight 15 pounds
Price $195.00 F. O. B. Pine Brook, N. J.

• THE MEGA-SWEEP

Wide Range Sweeping Oscillator
*** DISPLAYS PASS BAND**

FEATURES: Fixed and Variable Sweep Amplitude—High and Low level output. Carrier Frequency—50 Kilocycles to 500 megacycles and up . . . Frequency Sweep—from 30 megacycles to 30 kilocycles throughout the complete spectrum . . . Continuously variable attenuator . . . Low amplitude Modulation while sweeping—less than 0.1 DB per megacycle . . . Precision wavemeter. **Price $395.** F.O.B. Factory.

• The MEGA-MATCH

Visual Display of Reflected Energy

10 to 250 Mc and up. Completely electronic. No slotted lines, moving parts, bridges, or other frequency sensitive devices. Precision frequency meter. Saves engineering time. Presents instantly data which would take hours to tabulate. **$695.** F.O.B. factory.

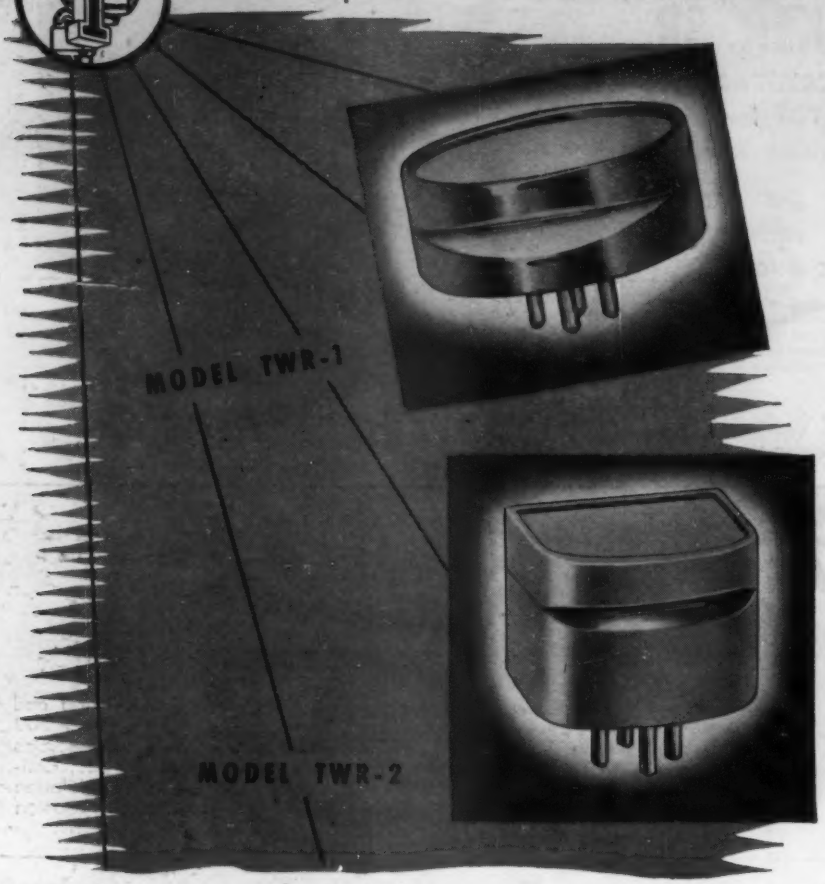
• THE MEGA-MARKER

Precision variable marker oscillator having a range of 19 to 29 megacycles for the television i.f. band. Crystal oscillator for the FM i.f. band (10.7 mc). Dial provides over 12 inches of calibrated scale length. May be read to accuracies of 0.02 megacycles. $60. F.O.B. factory.

KAY ELECTRIC CO., 25 MAPLE AVE., PINE BROOK, N. J.

Telephone: **CAldwell 6-3710**

now WIRE RECORDER HEADS BY TURNER



After months and months of designing, testing, and perfecting—Turner Engineers, working closely with the Armour Research Foundation, have developed these superior wire recorder heads. They are of the triple-purpose type, containing record, playback, and erase heads in one single, plug-in unit. Designed for replacement and new applications, the TURNER TWR-1 and TWR-2 are way over par in performance.

FOR A COMPLETE LINE OF MAGNETIC RECORDER HEADS TURN TO TURNER

If your manufacturing plans require magnetic recorder heads, it will pay you to consult Turner Engineers. Please write to EngineeringDevelopment, The Turner Company.

OUTSTANDING DESIGN AND CONSTRUCTION FEATURES

- Maximum fidelity. Superior "Y" groove for wire accurately cut by special machine* developed exclusively for Turner.
- Hum pickup held to absolute minimum by unique double-shielding construction.
- New triple-lamination structure greatly improves magnetic circuit.
- Controlled uniformity. Advanced design and manufacturing process assures uniformity of product.
- Beautiful chrome plated die cast housing.
- Engineered for exceptional performance.

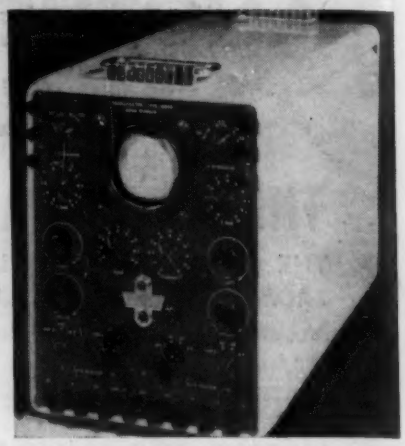
WRITE FOR BULLETIN

THE TURNER COMPANY

905 17th STREET N.E., CEDAR RAPIDS, IOWA

MICROPHONES AND OTHER ELECTRONIC EQUIPMENT

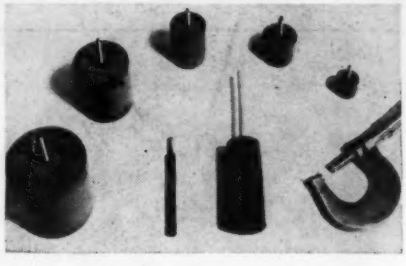
*Patent pending



Herts, England. A new oscilloscope of small dimensions designated type 1684D uses a 3½-in. tube. There is negligible phase shift from 0.2 cps to 3 mc. High-gain amplifiers are supplied for both axes and synchronizing voltage is equipped with automatic gain control. A catalog describing the whole line of scope and allied equipment is available.

Powder Iron Products

LENKURT ELECTRIC CO., 1113 County Road, San Carlos, Calif. The powder-iron core assemblies illustrated are typical of parts that can



be supplied in any powder desired. Outstanding features include minimum hysteresis and eddy-current losses. Standard items are available as well as those made to specifications.

Coaxial Connectors

KINGS ELECTRONICS CO., INC., 372 Classon Ave., Brooklyn 5, N. Y. A new line of midget coaxial connectors KP 6000, 7000, 8000, and 9000 can be used with type RG-57/U cable. The connectors and adapters are matched in impedance and will handle 50 watts

. . . or complete silence—**with controlled, constant d-c voltage**

Trained hands expect a pipe organ to respond immediately to any demand — from complete silence to a powerful crescendo. To meet these demands, hundreds of magnets and solenoids must have controlled d-c voltage on tap at all times.

In a growing number of installations, General Electric selenium rectifiers — specially designed and built for pipe organs — are supplying the smooth, constant voltage this application calls for. Over the full load range, these rectifier units give instant response — operate silently — at low cost.

*Trade-mark Reg. U. S. Pat. Off.

Tell G.E. your problem of d-c supply

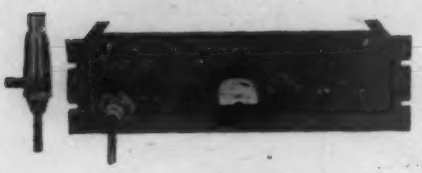
When you strike an unusual rectification problem — or even when the routine problem of deciding *which type* of rectifier is best for your purpose — call on General Electric for an answer. Because General Electric makes all three — selenium, copper oxide, and Tungar* — General Electric engineers can give you an impartial solution. Because G-E engineers know rectifiers — from the postage-stamp size to ten-ton monsters — they can give you the kind of *practical* solution you want. For information, write to A8-322, General Electric Company, Bridgeport 2, Connecticut.

G.E. makes all three
Selenium · Copper Oxide
Tungar
Rectifiers

GENERAL ELECTRIC

Announcing...

Equipment for Acoustical Measurements



CONDENSER MICROPHONE
Complement Type 100 B

Designed to facilitate precise and convenient measurement of Sound Pressure Level with the W. E 640 AA or other miniature condenser microphones.

FEATURES:

1. Small size preamplifier for minimum interference with sound field
2. Amplifies open circuit voltage to readily measured level
3. Highly stabilized gain
4. Automatically regulated bias voltage
5. Ideal for super-audible spectra
6. Individual calibration furnished
7. Completely A.C. operation furnishes minimum threshold noise

Price $655.00 FOB Los Angeles

★ ★ ★

THERMAL NOISE SOURCE
Type 300 A

A highly stable source of "white noise" spectrum for physical and physiological studies

FEATURES:

1. Amplifies electron noise generated in a cold resistor
2. Perfectly stable output—quantity and spectrum
3. Micro-noise spectrum amplified by highly stabilized 100 DB gain
4. Completely A.C. operated
5. All extraneous noises below thermal spectrum

Price $375.00 FOB Los Angeles

These instruments feature a new cabinet design furnishing convenient rack or table mounting and complete accessibility

Highly refined developments originating in war research and proven in succeeding industrial work

Send for detailed specifications
Distributed by ALTEC LANSING Corporation

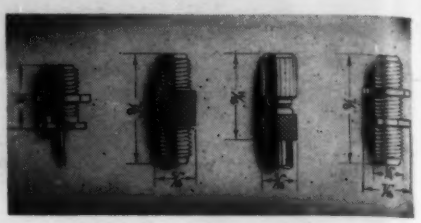
WESTERN ELECTRO-ACOUSTIC LABORATORY

PAUL S. VENEKLASEN, *Technical Director*
HENRY M. HARRIS, *General Manager*

621 S. SPRING STREET, LOS ANGELES 14, CALIFORNIA

YOUR HEADQUARTERS FOR ACOUSTICAL MEASUREMENTS

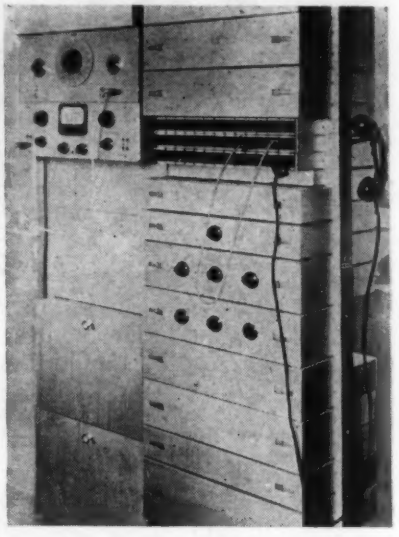
Watch for announcement of other instruments to complete a line of precision equipment



of r-f power. Soldered connections between inner connector and center conductor are not necessary. A single catalog sheet is available.

Eleven-Channel Carrier

LENKURT ELECTRIC CO., 1113 County Rd., San Carlos, Calif., introduces a new carrier system designed to provide as many as eleven duplex voice channels on a two-way



radio circuit. Type 42 was developed especially for installations where cables are economically impracticable. On installation, carrier equipment is required only at the terminals of the radio line; but carrier channels can be terminated or connected to side circuits at any repeater point with appropriate equipment.

Coiled Test Leads

KOILED KORDS, INC., Box K, Hamden, Conn. Retractile test cords in conventional black and red colors are made in 48-inch retracted lengths that can be extended to 20 feet. Coils can be cut to any de-

THE PROBLEM:

How to simplify modern electronic instruments ... get better control with fewer control units?

THE ANSWER:

THE BECKMAN Helipot

(trademark of the HELIcal POTentiometer)

– almost 12 Times* the Resistance Control in Same Panel Space as Conventional Potentiometers!

Cutaway view of the Helipot

ON PRODUCT after product the story is the same – the Helipot is revolutionizing potentiometer applications, simplifying control operations, and even making possible advanced electronic instruments impractical with other types of potentiometers. Widely used on precision electronic instruments during the war, the Helipot is an entirely *new* type of potentiometer which every electronic manufacturer and user should investigate.

Briefly, here's the Helipot principle ... whereas a conventional potentiometer consists of a *single* coil of resistance winding approximately 4" long, the Helipot has a potentiometer wire approximately 46"* long coiled *helically* into a case which requires *no more panel space* than the conventional unit. By means of a simple guide, the slider contact follows the helical path of the resistance winding from end to end as a single knob is rotated. Result ... almost *twelve* times the amount of control – far greater accuracy, finer settings, greater range – *at no increase in panel space requirements!*

Let us study your potentiometer applications and suggest how the Helipot can be used – possibly already is *being* used by others in your industry – to simplify control operations, get greater accuracy and range, and increase the utility of modern electronic equipment. No obligation, of course. Write today outlining your problems.

HIGH LINEARITY—as a result of fulfilling large wartime requirements for ultra-precision circuit controls, Helipots are mass-produced with linearity tolerances of one tenth of one percent—and even less!

WIDE RANGE—By coiling a long potentiometer slide wire into a helix, the Helipot provides many times the range possible with a single turn unit of comparable diameter and panel space.

PRECISE SETTINGS—Because of the many-times-longer slide wire, settings can be made with an accuracy impossible with single turn units.

LOW TORQUE—Of special interest for power-driven applications—the Helipot has unusually low torque characteristics. The 1½" Helipot, for example, is available with a torque of only 1 inch/ounce.

***HELIPOTS ARE AVAILABLE IN 3 STANDARD SIZES:**

TYPE A—5 watts, incorporating 10 helical turns and a slide wire length of 46 inches, case diameter 1¾", is available with resistance values from 10 ohms to 50,000 ohms.

TYPE B—10 watts, with 15 helical turns and 140" slide wire, case diameter 3¼", is available with resistance values from 50 ohms to 200,000 ohms.

TYPE C—2 watts, with 3 helical turns and 13½" slide wire, case diameter 1¾", available in resistances from 5 ohms to 15,000 ohms.

The Type B is also available in special sizes of 25 and 40 helical turns, with resistances ranging from 100 ohms to 500,000 ohms, and containing more than 100,000 change-of-resistance steps.

*Data above are for the standard Type A unit.

Send for the New Helipot Booklet!

Ask also for data on the DUODIAL *– the new turns-indicating dial ideal for use with the Helipot as well as with other multiple-turn devices!*

THE HELIPOT CORPORATION, 1011 MISSION STREET, SOUTH PASADENA 2, CALIFORNIA

Here's how to harness that "shortage" nightmare

To get supplies and equipment *fast* and lick your shortage problems, specify shipment by Air Express. It's the *fastest possible way* to ship and receive. There's no time wasted at airports because Air Express goes on every flight of the Scheduled Airlines. And you get door-to-door service at no extra cost.

Rates are so low it pays you to use Air Express regularly. And Air Express is inexpensive for the heaviest weight shipments, too. Standardize on this speedy, low-cost business service.

Call on Air Express

Specify Air Express—World's Fastest Shipping Service

- Low rates—special pick-up and delivery in principal U. S. towns and cities at no extra cost.
- Moves on all flights of all Scheduled Airlines.
- Air-rail between 22,000 off-airline offices.

True case history: Trailer replacement parts are regularly Air Expressed from Kansas City factory. Keeps valuable equipment rolling. Typical shipment: 31-lb. carton picked up 2 P.M. the 11th, delivered Los Angeles, Cal., the 12th, 7 A.M. 1360 miles, Air Express charge only $13.32. Any distance inexpensive, too. Phone your local Air Express Division, Railway Express Agency, for fast shipping action.

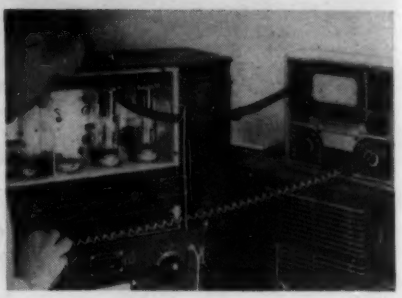
AIR EXPRESS

GETS THERE FIRST

Rates include pick-up and delivery door to door in all principal towns and cities

AIR EXPRESS, A SERVICE OF RAILWAY EXPRESS AGENCY AND THE

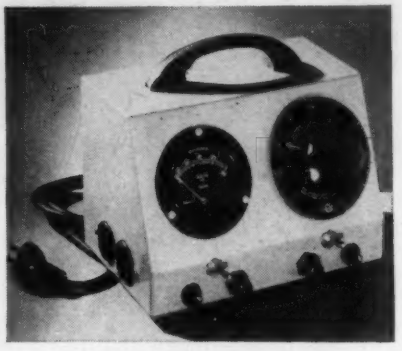
SCHEDULED AIRLINES OF THE U. S.



sired length for ultimate use. The ratio of retracted to extended length is 1 to 5.

Voltage-Control Box

ANDREW TECHNICAL SERVICE, 111 E. Delaware Place, Chicago 11, Ill. The portable voltage-control box pictured contains a 405-watt vari-



able autotransformer and a 0 to 150 voltmeter. Input rating is 115 volts, 60 cycles, single phase. Output is variable from 0 to 135 volts. Maximum current is 3 amperes.

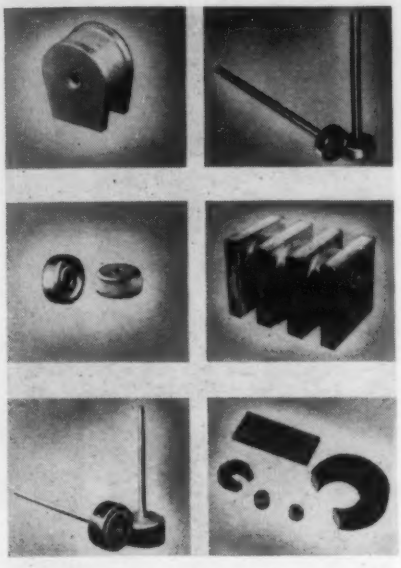
Wire Recorder

WEBSTER-CHICAGO CORP., 5610 W. Bloomingdale Ave., Chicago 39, Ill. Model 78 wire recorder features

push-button controls and comprises a wire mechanism, amplifier, oscillator and built-in power supply. A calibrated recording-level meter is also included.

Permanent Magnets

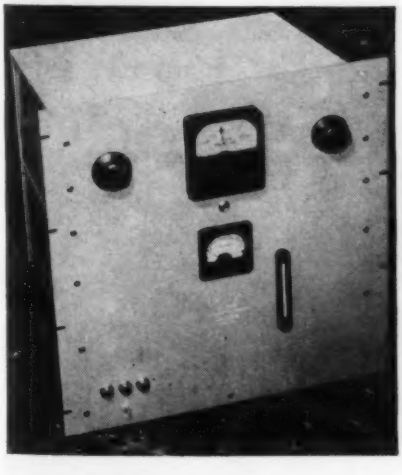
GENERAL ELECTRIC CO., Pittsfield, Mass. The standard line of Alnico permanent magnet holding assemblies consists of 5 types in 17 sizes,



many of which are illustrated. The assemblies can be used in snap-action devices, or as supports for ferromagnetic parts.

A-M Frequency Monitor

GATES RADIO CO., Quincy, Ill. MO-2890 frequency monitor for a-m broadcasting was recently approved by the FCC. It has a specially ground crystal in a new type anti-



PRECISION CONTROL

calls for HAYDON Timing

Combustion safeguard mechanisms require precision, ruggedness and quality construction in every component . . . that's why Wheelco Instruments Company chose Haydon timing for their extremely dependable Model 1131A Flame-otrol. This Wheelco safety device not only shuts off both main and pilot valves immediately on flame failure, but also provides a time delay for purging the chamber of combustible gases before relighting can be attempted . . . Haydon's #1600 series motor provides the accurate timing element.

Haydon motors are widely used in many combustion control devices such as day-and-night thermostats; stoker controls, oil burner controls, safety devices, etc. There is a Haydon unit to meet every timing requirement . . . 9 different motor series, hundreds of speeds from 450 rpm to 1 revolution per 1000 hours . . . variations to fit your specifications.

Typical of constant engineering advances is a new Haydon slow speed motor, soon to be available for 1 revolution per 12 hours, 1 day and 1 week . . . inexpensive timing for thermostats, switches and control equipment.

Take advantage of Haydon timing experience; have a representative call. Write for the new Haydon Engineering Data Catalog.

Write Haydon, 2404 Elm Street, Torrington, Connecticut

HAYDON

MANUFACTURING COMPANY, INC.

TORRINGTON CONNECTICUT

HARNESS TIME TO YOUR PRODUCTS

SUBSIDIARY OF GENERAL TIME INSTRUMENTS CORPORATION

AMPERITE
MICROPHONES

The ultimate in microphone quality, the new Amperite Velocity has proven in actual practice to give the highest type of reproduction in Broadcasting, Recording, and Public Address.

The major disadvantage of pre-war velocities has been eliminated—namely "boominess" on close talking.

- *Shout* right into the new *Amperite Velocity*—or *stand 2 feet away*—the quality of reproduction is always excellent.
- *Harmonic distortion is less than 1%* (Note: best studio diaphragm mike is 500% higher).
- *Practically no angle discrimination . . . 120° front and back.* (Best studio diaphragm microphones—discrimination 800% higher).

P. G. Dynamic
Models PGH, PGL
List $32.00

- One Amperite Velocity Microphone will pick up an entire symphony orchestra.

STUDIO VELOCITY, finest in quality; ideal for broadcasting and Recording.
Models R80H, R80L. List $80.00
There is an Amperite Microphone for every requirement.

WRITE FOR ILLUSTRATED 4-PAGE FOLDER giving full information and prices.

AMPERITE
Velocity Microphones
for Public Address
Models RBHG, RBLG
List $42.00

"Kontak" Mikes
Model SKH, list $12.00
Model KKH, list $18.00

In Canada:
Atlas Radio Corp.
560 King St. W.
Toronto, Ont.

AMPERITE Company
561 BROADWAY NEW YORK

Address inquiry attention Dept. E

SYNCHRON
TRADE MARK
TIMING MOTORS AND TIME MACHINES

Synchronous
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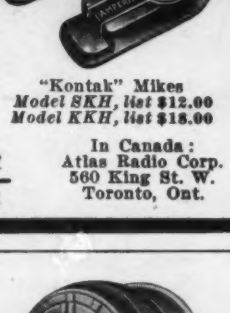
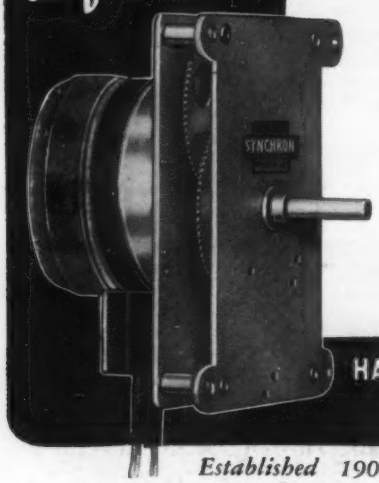


For Sustained Accuracy and Full Rated Power on Quick Starts

Ask any time machine maker—any electric clock repair man—what motor outlasts all others, and he'll say "SYNCHRON". In these tiny motors, all pinions and shafts are of steel, operating against polished brass gears—for least possible wear. All bearings are genuine Babbitt, lubricated by a sealed-in supply of oil surrounding all moving parts (patented process). SYNCHRON timing motors and time machines are designed, patented, and built for dependable, trouble-free service.

A new catalog containing engineering data on SYNCHRON Motors, Timing Machines, and Clock Movements will give you detailed information. Write for it.



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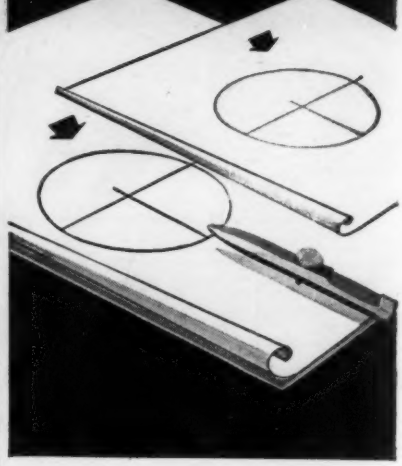

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adjustable autotransformers is type V-20 that handles 20 amperes at 115 volts. Output voltage is continuously variable from zero to 17 percent above input line voltage. Terminal box is designed for BX or conduit.

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MILES REPRODUCER CO., INC., 812-814 Broadway, New York 3, N. Y. Telemike, a midget telephone induction interceptor, requires no elec-

trical connection with the telephone or wire. It picks up both sides of the telephone conversation for group loudspeaker listening or for recording purposes.

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TRACERLAB, INC., 55 Oliver St., Boston 10, Mass. Model SU-3 labora-

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For Quick, Accurate Measurement of Capacitance and Inductance

PERMITTING measurements directly at radio frequency of a wide range of capacitance and inductance, the YCL-1 is a most valuable equipment for production, research and industrial laboratories.

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This General Electric Capacitometer is suitable for portable use, or it may be removed from the cabinet and mounted in a standard nineteen (19) inch relay rack.

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ACCURACY:	**± 1 micromicrofarad or 0.1%, whichever is larger**
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For complete information on the YCL-1 Capacitometer and other precision equipments write: *General Electric Company, Electronics Department, Electronics Park, Syracuse, New York.*

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Be assured of maximum reception and trouble-free operation with Brach FM & TV antennas. They are recommended for their simplicity, ease of installation and durability by service-men, installation engineers and dealers. Brach features a complete line, engineered for maximum performance and to meet all individual problems and requirements.

All antenna kits are complete, containing a five foot steel mast, non-corrosive aluminum elements, ample down-lead, all necessary hardware and the Brach Universal Base Mount which permits a 360° rotation of the mast to any position on any type of building after the mount has been secured. Guy wires are also included and give complete protection and stability to the installation.

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BRACH MULTI BAND
FOR FM & TV #344
44-108 MC 174-216 MC
(Accessory Reflector Kit #344-R as illustrated)

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174-216 MC

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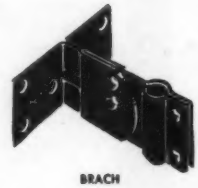
FOR FM #346
88-108 MC



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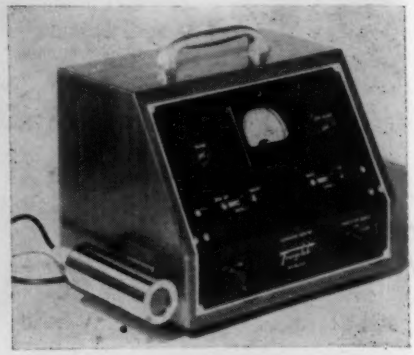
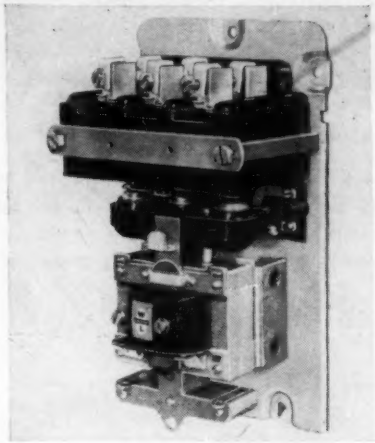


tory monitor has been developed as a routine contamination monitor for use in radioactivity laboratories. Either visual (counting rate meter) or audible (loudspeaker) indication is given. The device will pick up contamination from low energy beta emitters. A catalog sheet gives detailed specifications.

Solenoid Contactors

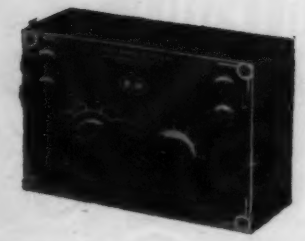
WARD LEONARD ELECTRIC CO., 31 South St., Mt. Vernon, N. Y. Intended primarily for use in a-c motor controllers, the Bulletin 4452



and 4453 solenoid contactors have maximum ratings of 25 and 50 h-p respectively on 440 or 550 volts, 3 phase, 60 cycles.

Audio Circuit Analyzer

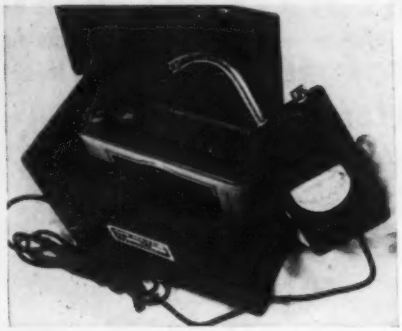
BARKER & WILLIAMSON, Upper Darby, Pa. The Sine Wave Clipper provides a test signal particularly useful in examining the frequency response and transients of audio circuits. By feeding the unit's output into audio equipment under test



and then introducing the equipment's output into an oscilloscope one can quickly view and analyze distortion introduced by the amplifier. Typical distortion patterns are furnished.

Air Velocity Meter

HASTINGS INSTRUMENT CO., Box 1275, Hampton, Va. An air velocity meter that will accurately measure velocities as low as five feet per



minute incorporates a noble-metal thermopile and a large accurate meter. Apparatus can be operated from power line or battery pack. Write for Bulletin 1047.

Program Equalizer

CINEMA ENGINEERING CO., 1510 West Verdugo Ave., Burburbank, Calif. The 4031-B program equalizer is designed for broadcast and recording studios. Equalization of 12 db at 100 cycles is provided as well as 3, 5, and 10 kc in calibrated 2-db steps. High- and low-frequency attenuation up to 16 db is accomplished by counterclockwise rota-

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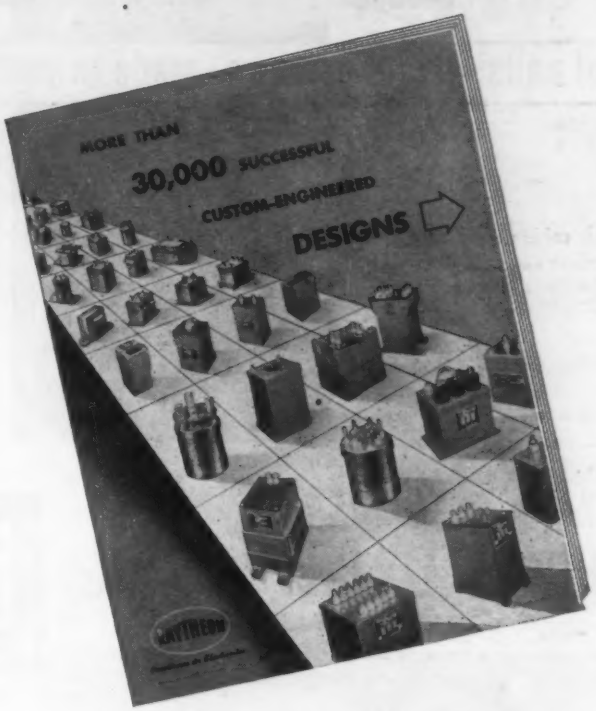

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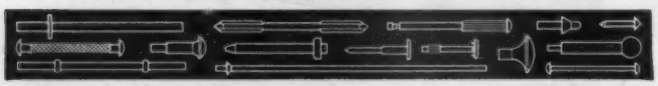

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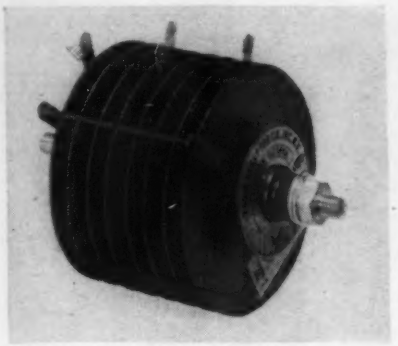
tion of the same control. More than 1,465 curve combinations can be obtained. The unit has an insertion loss of 14 db in a 500-to-600 ohm circuit.

Power Rectifiers

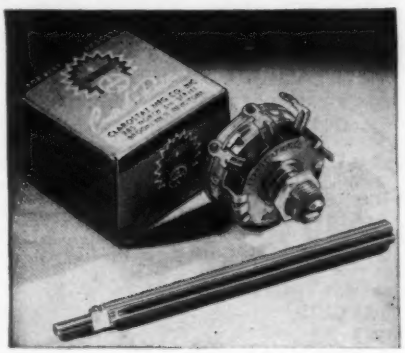
RADIO RECEPTOR CO., INC., 251 West 19th St., New York 11, N. Y. A new line of selenium power recti-



fiers includes 19 types required by laboratories, test departments, radio amateurs, and those engaged in similar work. A 5-page illustrated bulletin is available.

Clutch Volume Controls

CLAROSTAT MFG. CO., INC., 130 Clinton St., Brooklyn, N. Y. The SD series of volume controls available in type Z taper values from 250,000



ohms to 2 megohms is now obtainable with slip-drive. When the control shaft is turned beyond the end limits slippage is provided to avoid damage.

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TINNERMAN PRODUCTS, INC., 2106 Fulton Road, Cleveland 13, Ohio.

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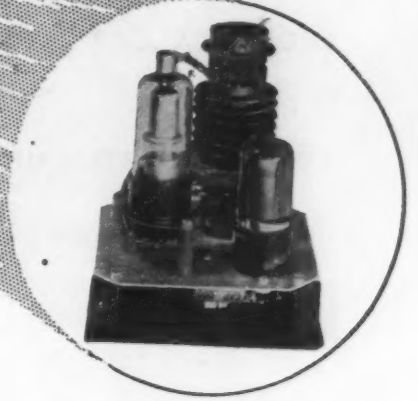

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4. These units are of the r.f. type and eliminate the hazards inherent in other types of high voltage power supply.

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	535–1620 kc	1.6–5.6 mc	5.6–19.25 mc	535–1620 kc	2.0–6.0 mc	6.0–18.0 mc	88–112 mc	TELEVISION
OSCILLATOR COIL	•	•	•	•	•	•	•	•
LOOP ANTENNA	•			•				
ANTENNA COIL	•	•	•	•	•	•		•
R-F INTERSTAGE TRANSFORMER	•	•	•	•	•	•	•	
BAND PASS ANTENNA COIL (Double Tuned)	•			•				
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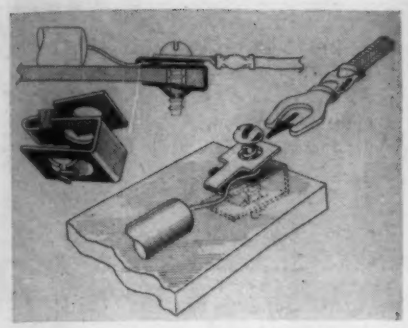
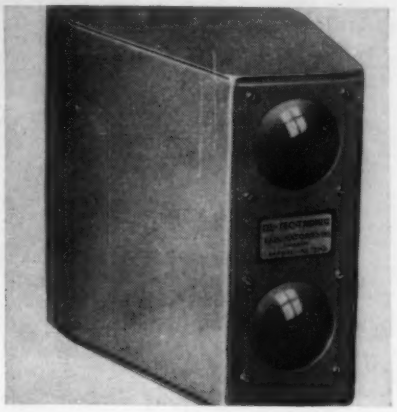


Leads with a spade terminal are placed under the head of the screw terminal while single-strand pigtails from capacitors and resistors are looped under the top member of the nut, around the screw, as illustrated. The entire connection is tightened by a single screw.

Electric Eye

DE-TEC-TRONIC LABS., INC., 1227 North Clark St., Chicago 10, Ill. Sentry electric eye announcer unit



comprises a photoelectric device and mirror. A break in the light beam actuates a bell or other warning. Maximum operating distance is about 25 feet. Unit operates on 115 volts, 60 cycles.

Plug-In Relay

GRAYHILL, 1 North Pulaski Road, Chicago 24, Ill. A new design relay is especially adapted for use in units such as food and drink dispensing machines that require fast servicing. Integral parts are mounted on a molded phenolic base to the bottom of which pin type connectors are affixed. Contacts handle

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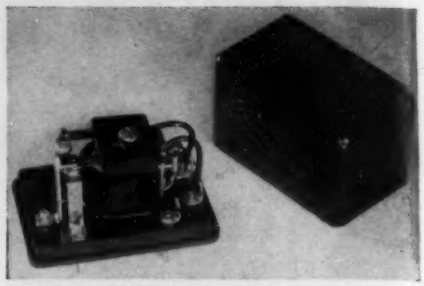
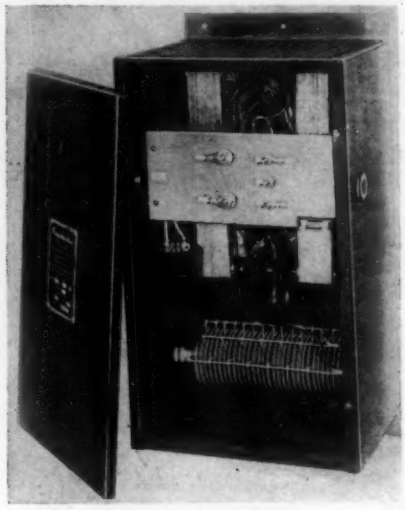


up to 10 amperes resistive load. The molded dustproof cover is optional.

Constant-Voltage Rectifier

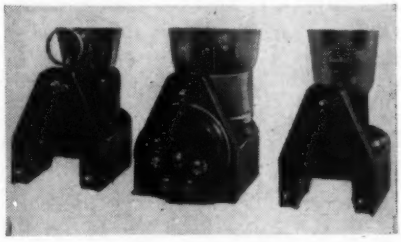
LA MARCHE MFG. CO., 6525 Olmsted Ave., Chicago 31, Ill. The selenium rectifier with a reactor type control which maintains constant d-c voltage has many potential uses



in the industrial field. It is a full-wave bridge type suitable for any a-c frequency and a line voltage of 115 to 230 volts.

Industrial Sockets

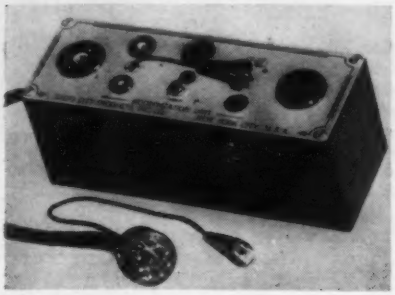
AMERICAN PHENOLIC CORP., 1830 South Fifty-Fourth, Chicago 50, Ill. Panel-mounting sockets for industrial tubes with either 4-pin UX



bases or superjumbo and industrial 4-pin bases are available with or without the back terminal block. Solderless screw terminals are used.

Tester Modernizers

RADIO CITY PRODUCTS CO., INC., 152 W. 25th St., New York 1, N. Y., has two models, 120 and 125, in its new modernization unit, designed to



meet the problem of obsolescent tube testers. Each has a flexible cable with a plug that is inserted into the socket of the old tube tester. New tubes are then tested in sockets provided in the units.

Milliammeter

MARION ELECTRICAL INSTRUMENT CO., Manchester, N. H. The Model 56 bakelite-encased meter is a large

dial instrument designed for easy reading at a distance. It has a 100-degree arc and a 5.5-inch scale length.

Portable Shop

RADIO CITY PRODUCTS CO., INC., 152 West 25th St., New York 1, N. Y. Model 8073 Servishop comprises tube tester, multitester, f-m signal generator, a-m signal generator, audio oscillator, and capacitor tester. The equipment is housed in

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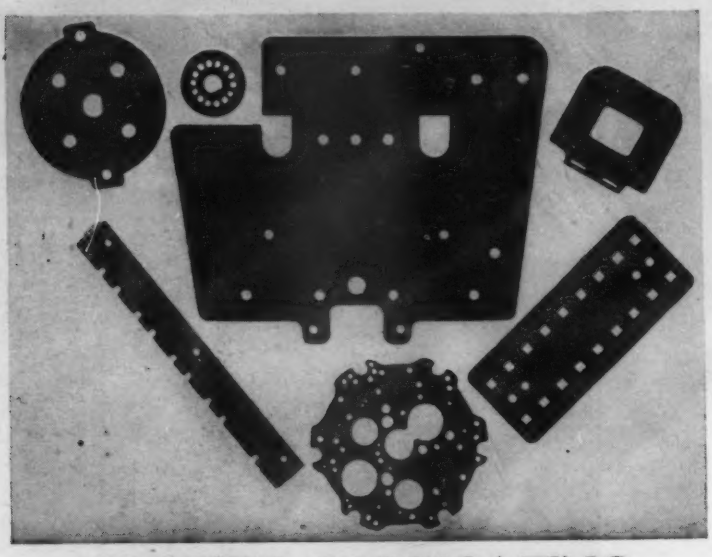

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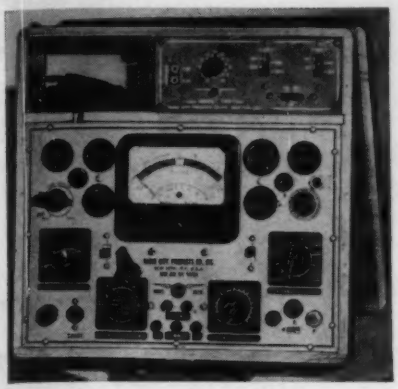

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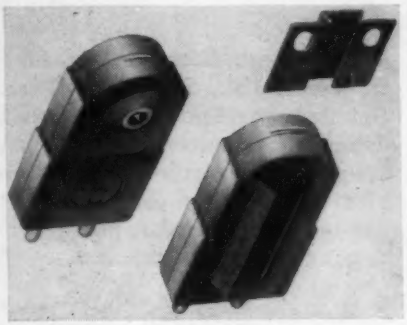

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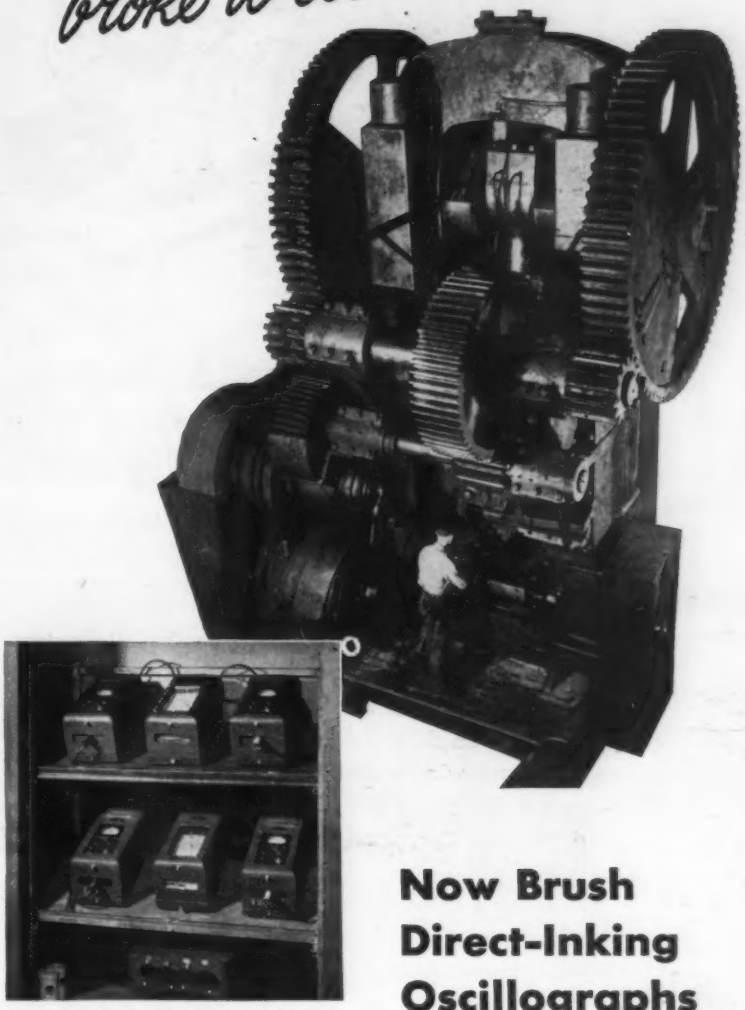

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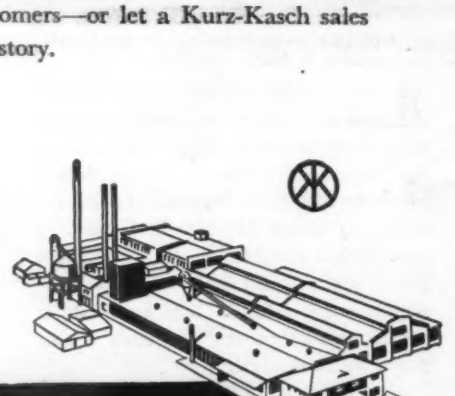

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Literature

Outlets. Alden Products Co., 117 North Main St., Brockton 64, Mass. Three types of power outlet and the 440 FH extractor fuse holder are fully described on sheet 8C.

R-F Heating Tubes. Machlett Laboratories, Inc., Springdale, Conn. A quarterly house organ gives an extensive technical description of the new line of r-f heating tubes, together with informative data in the forms of tables and graphs.

Multipurpose Microphones. Electro-Voice, Inc., Buchanan, Mich. Detailed specifications for crystal, dynamic, and carbon microphones are given in bulletin No. 137. Complete adaptability permits widest use in public address, paging, recording and communications.

Operation Recorder. Esterline-Angus Company, Inc., Indianapolis 6, Ind. Bulletin 247 contains a 16-page description of the operation recorder, its design features, methods of installation and applications.

Transmitting Tubes. United Electronics Co., 42 Spring St., Newark 2, N. J. Latest designs in tubes are illustrated in the new 12-page catalog, 1-GPW-7. Four new types of 30-kv vacuum capacitors are also described.

Electronic Housings. Par-Metal Products Corp., 32–62 49th St., Long Island City 3, N. Y. A variety of racks, panels, cabinets, chassis and parts are listed, described and illustrated in catalog 48. Also included is a two-page numerical index.

Cable Connectors and Vulcanizers. Mines Equipment Co., 4215 Clay-

ton Ave., St. Louis 10, Mo. Write for Price Section No. 105 which is a catalog listing with prices covering molded rubber connectors and receptacles. Bulletin RV106, on steam and direct-heat vulcanizers, is also available.

Tube Testers. The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland 8, Ohio. A complete line of indicating instruments and radio service equipment is described and illustrated in the 24-page catalog No. 145A. List and net prices for each model may also be obtained.

Radiation Instruments. The Victoreen Instrument Co., 5806 Hough Ave., Cleveland, Ohio. Several types of instrument for measuring different phases of radiation are pictured in a four-page folder. Operating characteristics of each are given.

Hearing-Aid Tubes. Raytheon Mfg. Co., 55 Chapel St., Newton 58, Mass., has issued a subminiature tube booklet dealing specifically with a variety of flat hearing-aid types. Included are electrical and mechanical data, characteristics, graphs, and outline drawings.

Timing Motor. The Bristol Motor Co., Forestville, Conn. Design, construction, applications and specifications of the Circle B a-c selfstarting, synchronous timing motor are set forth in a recent 4-page folder.

Parts Catalog. Bud Radio, Inc., 2126 E. 55th St., Dept. A, Cleveland 3, Ohio, has issued a catalog illustrating and describing over 1,100 different products in the radio parts field. Standard items and many new products are covered.

High-Vacuum Apparatus. Central Scientific Co., 1700 Irving Park Road, Chicago 13, Ill. High-vacuum pumps and a wide variety of accessories are covered in a 48-page pamphlet, Bulletin 10. Illustrations and complete technical data are included.

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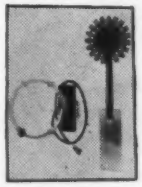

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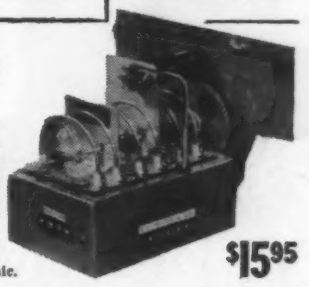

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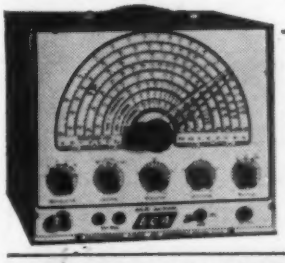

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St., New York, N. Y. Bulletin 50–65 treats of a series of sensative, multiple-arm relays adaptable to a wide variety of circuit arrangements. The pamphlet gives design features and ordering information.

Instrumentation. Hewlett-Packard Co., 395 Page Mill Road, Palo Alto, Calif. Catalog 18A, along with a 6-page folder and five single sheets deal with laboratory instruments designed for speed and accuracy of audio measurements. Complete description and specifications of each are given.

Broadcast Station Light. Cannon Electric Development Co., 3209 Humboldt St., Los Angeles 31, Calif. The type Q indicator light for broadcast stations, or whereever controlled warning lights are required, is described and illustrated in bulletin Q-1.

Oscilloscope Recorders. The Electrodyne Co., 899 Boylston St., Boston 15, Mass. Telemetering and ionosphere research oscilloscope recorders can be engineered to fit particular requirements. Sample specifications are found in a recently revised 4-page bulletin available at request on business letterhead.

Phase Monitor. Andrew Co., 363 E. 75th St., Chicago 19, Ill. Complete details of the type 40-C phase monitor are set forth in the recently issued bulletin 47.

Relative Humidity Recorder. Serdex Inc., 91 Cambridge St., Boston 14, Mass. The Microhygrograph, an instrument designed for accurate readings of minute fluctuations of relative humidity, is featured in bulletin No. 311.

Electrical Steels. The American Rolling Mill Co., 703 Curtis St., Middletown, Ohio. A new catalog deals with Tran-Cor X, XX, and XXX iron-silicon alloys developed especially for low core loss and high permeability in the rolling direction.

Tube Literature. Radio Corporation of America, Harrison, N. J., recently issued three 4-page pam-

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SN-3-T	FABRIC TREATMENT

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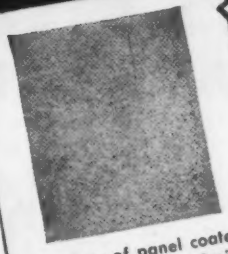
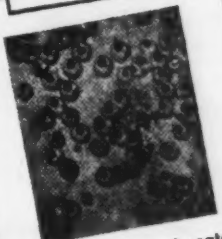


Close up of panel coated with ISNL-X "T" Series after 6 months exposure.



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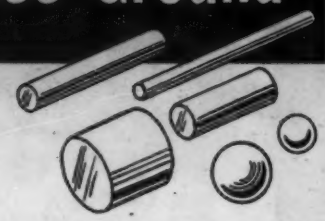

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phlets on electron tubes. AN-122 deals with compensation of frequency drift; AN-123, receiver microphonics caused by heater-cathode capacitance variations; and a technical bulletin covers the 6BH6, a miniature sharp-cutoff pentode.

Plastics Heaters and Welders. American British Technology, Inc., 57 Park Ave., New York 16, N. Y., distributors for Radio Heaters Ltd., Wokingham, England. Pamphlets describing various models of Radyne plastics preheaters and a plastics seam welder give complete specifications.

Selenium Rectifiers. General Electrict Co., Schenectady 5, N. Y. Bulletin ETR gives two pages of description and technical information on models 6RS5GH1, and 6RS5GH2, one-inch square selenium rectifiers.

Molded Bobbins. Mayfair Molded Products Corp., 4440 N. Elston Ave., Chicago 30, Ill. A four-page brochure shows available phenolic coil forms or bobbins. Special sizes can be molded to specification.

Data Sheet. The Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio. The VXR-130, a gaseous voltage-regulator tube intended for low-power applications, is discussed along with typical circuit and characteristics on data sheet 1.

Air-Flow Switches. Coral Designs, P.O. Box 248, Forest Hills, N. Y. Bulletin 101 treats safety switches for communication and industrial equipment using air-cooled electronic tubes. The switches described are designed to insure against tube failure due to lack of air flow.

Insulation Tester. American British Technology, Inc., 57 Park Ave., New York 16, N. Y. as distributors for Bowthorpe Electric Co., Ltd., Oxford, England, have a descrip-

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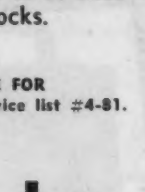
See our "Open Letter" advertisement on page 220—February 1948 issue of Electronics

CUSTOM BUILT FRACTIONAL H.P. MOTORS ....



.... ENGINEERED *"PRECISELY"*
to fit your most exacting applications

VARIABLE VOLTAGE DRIVES
LOW INERTIA DC MOTORS

DYNAMOTORS
either
Permanent Magnet
or
Wound Field

MOTOR GENERATOR SETS
UNIVERSAL MOTORS
SYNCHRONOUS MOTORS
SELSYNS (POWER TYPE)
SINGLE PHASE MOTORS
3 PHASE MOTORS
Capacitator Start
& Split Phase
Repulsion-Induction

ELEKRAFT MANUFACTURING CO.

8 ACKERMAN AVE. CLIFTON, N. J.

PRECISION Series 866
DUAL-SENSITIVITY

Push-button operated, panel mounted, Wide-Range AC-DC Test Set with full-view 9" meter & Remote Selector Unit.

5000 and 1000 OHMS PER VOLT D.C.
100 OHMS PER VOLT A.C.

Indispensable to the well equipped, electronics service-maintenance laboratory and classroom.

The extra-large 9" meter and remote-control selector unit afford unparalleled visibility and operational efficiency.

SPECIFICATIONS

★ 8 D.C. VOLTAGE RANGES:
5000 and 1000 ohms per volt
★ 8 A.C. VOLTAGE and OUTPUT RANGES:
1000 ohms per volt.
0-3-6-12-60-300-600-1200-6000 volts
★ 8 D.C. CURRENT RANGES:
0-.3-1.2-3-30-300-600 M.A.
0-1.2-12 Amperes
★ 6 RESISTANCE RANGES:
self-contained to 20 Megohms.
0-2000-20,000-200,000 ohms
0-2-20-200 Megohms
★ 9" 200 microamp. METER: 2% accuracy.
★ 1% Wire-wound & Metallized Resistors.
★ All standard measurements
at only two polarized tip jacks.
★ 6000 volt safety jacks.

866 (illustrated) In standard panel mount, size 19"x12¼" with rear dust cover 6" deep. Complete with high voltage test leads and ohmmeter batteries.
NET PRICE $64.85

See *the Precision line of electronic test instruments at all leading radio equipment distributors or write directly for complete 1948 catalog.*

PRECISION
APPARATUS CO., Inc.
92-27 Horace Harding Blvd.
Elmhurst 10, N. Y.

Export Division, 458 Broadway, New York City, U. S. A. Cables, MORHANEX

tive brochure on the Triometer, an insulation tester built around an alternating current generator. Resistance scale for several models is 0 to 50 megohms.

Speed Control. Yardeny Laboratories, Inc., 105–107 Chambers St., New York 7, N. Y., has recently issued information describing the Dyna-Link, a packaged speed control for variable speed transmissions

Insulation Testers. James G. Biddle Co., 1316 Arch St., Philadelphia 7, Pa. Bulletin 21–45 treats all phases of the hand-operated type of Megger insulation tester. Applications, specifications and prices are included.

Test Films. Society of Motion Picture Engineers, 342 Madison Ave., New York 17, N. Y. has prepared, in conjunction with the Motion Picture Research Council, a catalog of 16- and 35-mm test films. Films listed should prove valuable to television broadcasters and experimenters.

Portable pH Meter. Muirhead & Co. Ltd., Beckenham, Kent, England. Bulletin B-593-B describes and illustrates the type D-449-A portable instrument which includes all accessories for the measurement of pH in any location.

Tantalum. Fansteel Metallurgical Corp., North Chicago, Ill. In a 20-page, illustrated booklet, the physical, chemical, and electrical properties of the metal tantalum, a useful material in electronic tubes, are tabulated and discussed. Comparisons with some better-known metals are made.

Electronic Computer. Reeves Instrument Corp., 215 East 91 St., New York 28, N. Y. The Electronic Analogue Computer has been described in block-diagram style in a booklet just released. The instrument is especially suited for

Standardize on KESTER Cored Solders!

POSITIVE FLUX CONTROL

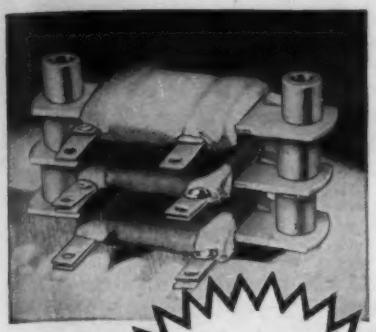
Be absolutely sure of the correct amount of flux and get perfect soldering results every time. Use Kester Cored Solders with their scientific, pure and uniform flux core.

Troubled with a difficult soldering operation? Consult our engineers on any soldering problem. No obligation to you.

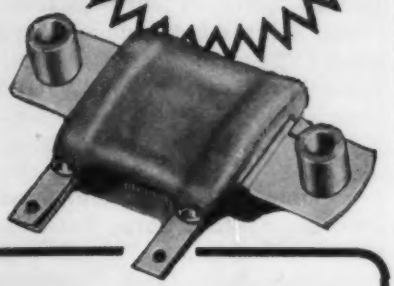
KESTER SOLDER

KESTER SOLDER COMPANY
4204 Wrightwood Ave.
Chicago 39, Illinois

FACTORIES ALSO AT
NEWARK, NEW JERSEY
BRANTFORD, CANADA



Stacked RESISTORS



Series ZT Greenohms for handy stacking.

Connected together or separately. Adequate spacing for cool operation.

Clearance of No. 10 screw through collars. 9/32" spacing required for each stacked unit.

Wire-wound. Famous Clarostat cold-setting inorganic Greenohm cement coating. Won't chip, flake, crack.

In standard 30, 40, 55, 65 and 75 watt ratings. Total resistance values of 10,000 to 50,000 ohms.

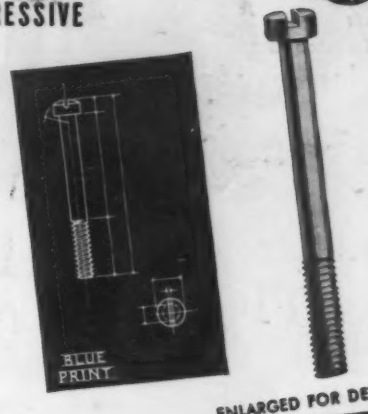
CLAROSTAT

Write for Bulletin 113. Let us quote on your needs.

Controls and Resistors

CLAROSTAT MFG. CO., Inc. · 285-7 N. 6th St., Brooklyn, N. Y.

ANOTHER SPECIAL BY PROGRESSIVE



CATALOG SHOWS DOZENS MORE

Special heads, threads and finishes on any metal or alloy adapted to cold upset. Weekly output: 25,000,000 pieces. Many specials, suggesting production savings for you, illustrated in latest catalog. Includes weights per 1M standard pieces, dec. equivs. of fractions, other purchasing and engineering helps. Write for Catalog 19.

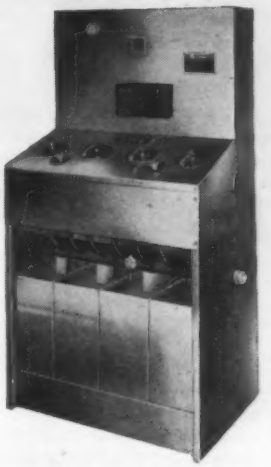
The PROGRESSIVE MFG. CO.
59 NORWOOD ST. TORRINGTON, CONN

The New Barnstead
UPFLO DEMINERALIZERS

Supply water of FAR HIGHER RESISTANCE with GREATER EASE and at LESS COST

THE newly developed principle used in these UPFLO Models plus the use of improved synthetic resins represents a notable gain in Barnstead's 70 year record of making purer water available to industry at an ever lower cost. The raw water flows UP through the resins which results in greater efficiency and entirely new simplicity of operation. Completely eliminates the need for backwashing. Valve operations are reduced and regeneration time cut nearly in half.

These compact, efficient, cost-saving units remove all metals such as sodium, potassium, calcium, magnesium, iron, copper, etc., as well as sulfates, carbonates, bicarbonates, chlorides, etc. Constructed of Stainless Steel. Flow rates from 3 to 100 Gallons per hour. Other Barnstead demineralizers up to 1,000 gallons per hour.



Pictured above is Model FR-2, Four-bed Double-action Upflo Type with a flow rate of 80 gals per hour.

Send for Bulletin 117 for full details

Barnstead
STILL & STERILIZER CO. Inc.

228 Lanesville Terrace Forest Hills, Boston 31, Mass.

More EFFICIENCY APPLICATIONS VALUE

by using these NEW RACON SPEAKERS and HORN UNITS

Right — NEW RADIAL RE-ENTRANT SPEAKER, excellent for all types of industrial sound installations, provides superlative and complete 360° speech intelligibility by efficiently over-riding factory high noise levels. Frequency response 300-6000 cps. Handling capacity 25 watts continuous, 35 w. peak. Has mounting bracket. Size 12" wide by 12 ⅝" high.

Left — NEW SMALL RE-ENTRANT HORNS, extremely efficient for factory inter-com and paging systems; for sound trucks, R. R. yards and all other industrial installations where high noise levels are prevalent. Watertight, corrosion-proof, easily installed. Two new models—type RE-1 1/2, complete with Baby Unit, handles 25 watts, covers 300-6000 cps; type RE-12, complete with Dwarf Unit, handles 10 watts, has freq. response of 400-800 cps.

Right—NEW SPECIAL PM HORN UNIT, having Alnico V magnet ring completely watertight, housed in a heavy aluminum spinning. Provides extremely high efficiency reproduction with minimum input. Handling capacity 35 watts continuous, 60 w. peak.

To the more than 60 different type and size speakers and horn units that already comprise the RACON line—these new models have been added. There is a RACON speaker and horn unit ideal for every conceivable sound system application. RACON has not only the most complete line, but also has the most preferred line. For over 20 years leading Soundmen have recognized and specified them because of dependability, efficiency and low-cost, and because the reproducers are trouble proof.

RACON ELECTRIC CO., INC.

52 E. 19th St., New York 3, N. Y.

RACON

Write for catalog describing RACON'S Line of Horns, Speakers, Units, Accessories, Inc.

industrial applications, and for research groups requiring rapid dynamic solution of differential equations with a minimum of trained personnel.

Autotransformer. General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass. An eight-page, two-color pamphlet describes and illustrates three new types of Variac, a continuously adjustable autotransformer.

Price and Data Sheets. Western Union Telegraph Co., Electronics Research Division, Watermill, L. I., N. Y. A single page covers description of the type K300AC 300-watt concentrated-arc lamp and type WM175 power-supply unit. Attached is a price list for a variety of these units.

High-Gain Beacon Antenna. The Workshop Associates, Inc., 66 Needham St., Newton Highlands 61, Mass. One side of a sheet covers the redesigned 152–162 mc high-gain beacon antenna. A variety of constant-impedance connector adaptors with their prices is also listed.

Catalog. Allied Radio Corp., 833 W. Jackson Blvd., Chicago 7, Ill. The 172-page 1948 catalog includes over 10,000 radio and electronic items with special emphasis placed on equipment for industrial maintenance, research and production requirements as well as for the needs of government agencies.

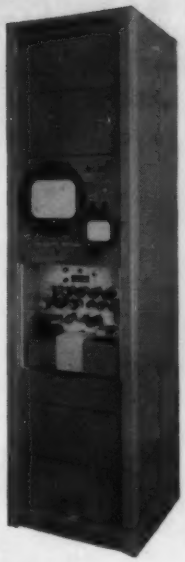
Communications Equipment. J. H. Bunnell Co., 215 Fulton St., New York 7, N. Y. A handsomely-bound and well-illustrated catalog covers standard and contract telegraph communication equipment from buzzers to carrier systems.

Carrier Telephone System. Lenkurt Electric Co., 1113 County Rd., San Carlos, Calif. Bulletin 62A is a 68-page engineering report on the type 32 carrier telephone sys-

POLARAD
TELEVISION *Equipment*
for studio • laboratory • manufacturer

PICTURE & WAVE FORM MONITOR

Model M102



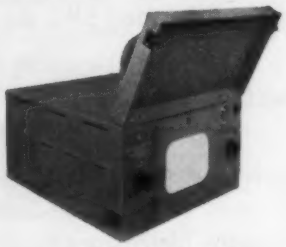
FEATURES:

- Resolution greater than 600 lines.
- 10" Kinescope and 5" oscilloscope.
- Built-in Bar Generator for checking horizontal and vertical linearity.
- Horizontal and Vertical Pulse Cross phaseable over entire Kinescope.
- All controls accessible from front of rack.
- All parts readily accessible for quick servicing and testing.
- Monitor section occupies 17½"x19" panel space and may be mounted at a remote point.
- Video input high impedance.
- May be operated by either driven or composite signals.
- Voltage calibrator for Wave Form Monitor.

Specifications

Input impedance of Picture Monitor 470,000 ohms.
Picture Amplifier: Flat to 7.5 Mc ± 1 db.
Scope Amplifier: Flat to 3. Mc ± 1 db.
Input Signal: 1 Volt peak to peak.
115 volts 50/60 cycles—6 amps.
Complete with tubes in a rack 83"x22"x22".

Portable Picture Monitor



MODEL 102 MPS

FEATURES:

- Resolution 500 lines.
- 7" Kinescope.
- High Impedance Input.
- Rugged construction.
- Size 9"x16"x20", weight 50 lbs.
- Kinescope removable from front and all parts are readily accessible.

SPECIFICATIONS:

- Input Impedance 470,000 ohms.
- Video Amplifier: Flat to 5 Mc ± 1 db.
- Input Signal: 1 volt peak to peak.
- 115 volts 50/60 cycles.
- Complete with tubes.

Dual Portable Picture Monitor

MODEL 102 MPD

This unit has the same performance and constructional features as the single portable monitor. This unit is supplied in two carrying cases consisting of a control unit and the dual monitor unit. Each monitor may be used independently of the other.

Polarad *Electronics Company*

9 FERRY STREET, NEW YORK 7, N. Y.

Television engineers and consultants to the nation's great television stations.

VULCAN

Pygmy

The "pencil type"
ELECTRIC SOLDERING TOOL
for delicate soldering jobs

¼" diameter
▼ screw tip

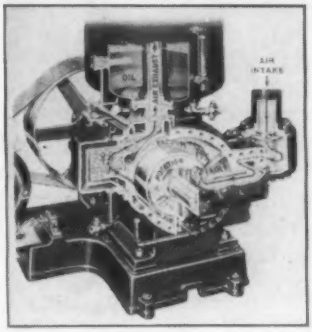
▲ Cool, tapering wood handle permits "writing" grip.

▲ Flexible coil insures cool handle and aids in reaching tight spots.

VULCAN ELECTRIC COMPANY
DANVERS 10, MASS.

MAKERS OF A COMPLETE LINE OF ELECTRIC SOLDERING TOOLS—SCREW TIP—PLUG TIP—PYGMY—MERCURY—ELECTRIC GLUE POTS—ELECTRIC SOLDERING POTS AND OTHER ELECTRICAL HEATING DEVICES.

Unique Design of Single Stage Pump Produces High Vacuum Faster, More Efficiently and Safely



The pump has only 2 moving parts — rotor and slide valve, always completely sealed in pump cylinder. As rotor turns, slide valve acts as piston forcing all air out of cylinder through discharge valve and lubricator above it, creating a constant vacuum behind the slide valve piston.

The combination of mechanical inlet slide valve, automatic exhaust valve, and rotary pump with rocker oil seals on slide valve, account for the unusually high vacuum and volumetric efficiency in this single stage pump.

for

ELECTRONICS AND LAMPS

Vacuum exhausting at low pressures of lamp bulbs, fluorescent tubes, radio, television and electronic tubes, X-ray tubes, photo-electric cells, etc.

ELECTRICAL PRODUCTS

High vacuum impregnation of coil windings to give greater strength; dehydration and impregnation of molded or compressed graphite parts; deairing, drying and impregnating insulating paper, cable, motor windings; dehydrating insulating oil; filling condensers.

ADVANTAGES

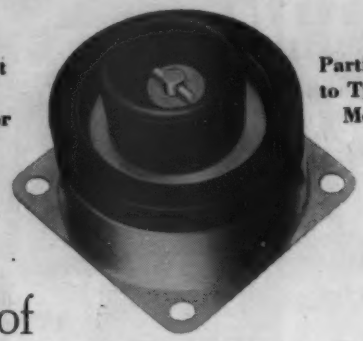
- Top Vacuum — to 2 microns
- High Speed Evacuation
- Noiseless • Vibrationless
- Low Power Consumption
- Long Service Life
- Capacities to 845 c.f.m.

Write for Catalog No. 84

BEACH-RUSS COMPANY
52 CHURCH ST., NEW YORK 7, N. Y.

BEACH-RUSS *TYPE RP* **VACUUM PUMPS**

Type M-112 Unit
Aircraft
Vibration Isolator



Particularly adapted to Type MT Aircraft Mounting Racks.

Control of
VIBRATION and IMPACT

. . . with special emphasis on the field of electronics

We offer a complete line of highly engineered Vibration and Impact isolators for commercial, industrial and military applications. . . also an Engineering consulting service on special problems.

A letter from you will give us the opportunity to demonstrate how we can help you.

Catalogue on request

THE BARRY CORPORATION
Formerly L. N. BARRY CO., INC.
177 SIDNEY STREET
CAMBRIDGE, MASS.

BALLANTINE ELECTRONIC VOLTMETER,
DECADE AMPLIFIER and MULTIPLIERS

10 MICROVOLTS to 10,000 VOLTS

ONE BILLION TO ONE—This enormous range of AC voltages—is easily covered by the Model 300 Voltmeter, Model 220 Decade Amplifier and Model 402 Multipliers illustrated above. The accuracy is 2% at any point on the meter scale, over a frequency range of 10 cycles to 150 kilocycles. The Model 300 Voltmeter (AC operated) reads from .001 volt to 100 volts, the Model 220 Amplifier (battery operated) supplies accurately standardized gains of 10x and 100x and the Model 402 Multipliers extend the range of the voltmeter to 1,000 and 10,000 volts full scale.

Descriptive Bulletin No. 10 Available

BALLANTINE LABORATORIES, INC. BOONTON, NEW JERSEY, U.S.A.

tem. Included are frequency allocations for carrier telephone and descriptions of the terminals, repeaters, pilot regulators, and auxiliary units.

Radio Products. Alden Products Co., 117 North Main St., Brockton 64, Mass. Three loose-leaf inserts cover a line of widely varied insulated tube caps, wire leads, and molded parts or service now available.

Dynamotor. Bendix Aviation Corp., Red Bank, N. J. A four-page folder treats a line of dynamotors built small and light for compact mobile radio installations. Performance characteristics are shown.

Communications Equipment. Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30, Pa. Booklet B-3945 describes and illustrates new point-to-point radio communication equipment. Design features, and electrical and mechanical characteristics are given.

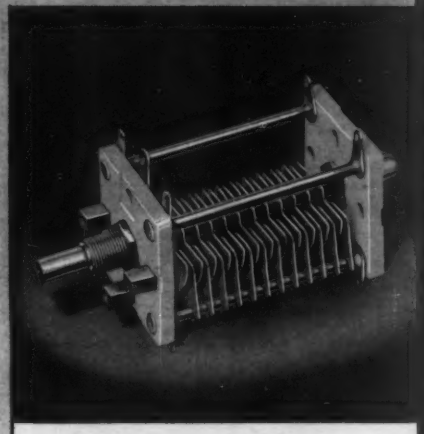
Continuous Tuner. Allen B. DuMont Laboratories, Inc., Passaic, N. J., has issued a bulletin on the Inputuner, a tuner and r-f head covering all television and f-m channels continuously from 44 to 216 mc. Input circuit is low impedance.

Stringed Instrument Pickup. Electro-Voice, Inc., Buchanan, Mich. Bulletin 136 contains complete specifications and instruction for mounting and detaching the Model 80 contact pickup microphone for stringed instruments.

Tape Recording. Amplifier Corp. of America, Magnephone Division, 398 Broadway, New York 13, N. Y. A booklet written by the chief engineer discusses the history and advantages of magnetic tape recording. Included are schematic and block diagrams, and a classified list of possible applications. The booklet is available postpaid upon receipt of twenty-five cents in stamps or coin.

Designed for

Application



The 23000 Series
Variable Air Capacitors

"Designed for Application," double bearings, steatite end plates, cadmium or silver plated brass plates. Single or double section. .020" or .060" air gap. End plate size: 1⅞ x 1½. Rotor plate radius: 1⅝". Shaft lock, rear shaft extension, special mounting brackets, etc., to meet your requirements.

JAMES MILLEN MFG. CO., INC.

MAIN OFFICE AND FACTORY
MALDEN
MASSACHUSETTS

(continued from p. 148)

Commission to accommodate the terrain proximity indicator. This will enable air carriers to use existing war surplus equipment operating in this band while equipment designed for permanent operation in the band is being developed. The aeronautical service will vacate not later than February 15, 1950. Manufacturers and users of terrain proximity indicators were urged by the Commission to take immediate action on development and procurement for operation on the permanently assigned 4,200-4,400 mc band.

New Frequencies Available

IN ACCORDANCE with the Atlantic City Radio Regulations, the FCC has announced that the frequencies 915, 2,450 and 5,850 mc may be used in all countries of the Americas for industrial, scientific and medical services.

The frequencies available for these services (reported tentatively in February 1948 ELECTRONICS p 242) are summarized in final form as follows:

Assigned Band	Center Frequency & Tolerance
13,553.22-13,566.78 kc	13,560 ±6.78 kc
26,960.00-27,280.00 kc	27,120±160.00 kc
40,660.00-40,700.00 kc	40,680 ±20.00 kc
890.00- 940.00 mc	915 ±25.00 mc
2,400.00- 2,500.00 mc	2,450 ±50.00 mc
5,775.00- 5,925.00 mc	5,850 ±75.00 mc
10,500.00-10,700.00 mc	10,600±100.00 mc
17,850.00-18,150.00 mc	18,000±150.00 mc

BUSINESS NEWS

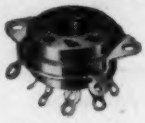
ELECTRONIC ASSOCIATES, INC., has moved to large and more modern laboratories and shops at North Long Branch, N. J. The new plant comprises five buildings with 36,000 sq ft of floor space.

AUDIO EQUIPMENT CO., INC., Elmhurst, N. Y., was recently formed for the manufacture of portable electric megaphones and other audio-electronic equipment.

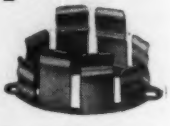
CARNEGIE INSTITUTE OF TECHNOLOGY has begun construction of the building for housing the new synchro-cyclotron on its recently purchased 60-acre site at Saxonburg, Pa. The cyclotron is expected to be in operation early in 1950. Total cost of the project will be about a million dollars. The apparatus will have a 1,000-ton electromagnet and

If you need Radio Parts...

in quantities suitable to Volume Production...it may pay you to call upon the Design Engineers of United-Carr and its



subsidiaries. They have helped many manufacturers



★ CUT COSTS
★ SPEED PRODUCTION
★ TURN OUT FINER FINISHED PRODUCTS

UNITED-CARR FASTENER Corp.
CAMBRIDGE 42, MASSACHUSETTS

MAKERS OF DOT FASTENERS

precision-fabricated

PLASTIC DIALS

QUALITY and SERVICE AT A PRICE THAT'S RIGHT

You can't go wrong when you depend on Sillcocks-Miller for plastic dials. These experienced engineers are recognized throughout the industry for their ability to fabricate plastic materials to close tolerances. The combination of this skill and complete production facilities provides a dependable source for the quality and service you want—at a price that's right.

Write for illustrated booklet or phone South Orange 2-6171 for quick action.

THE SILLCOCKS-MILLER CO.

10 West Parker Avenue, Maplewood, N. J.
Mailing Address: South Orange, N. J.

SPECIALISTS IN HIGH QUALITY, PRECISION-MADE PLASTICS FABRICATED FOR COMMERCIAL, TECHNICAL AND INDUSTRIAL REQUIREMENTS

THE TINY MITE . . . a NEW relay

Blessed Event in Advance Family

Advance is pleased to introduce the newest and smallest member of its family — Tiny Mite. This 0.35 cubic inch relay is, to the best of our knowledge, *the world's smallest relay*. Contacts are SPDT and rated at .35 amps 60 VDC or 115 VAC (resistive load). Laminated phenolic keeps contacts above ground. The average power requirement is from .35 to .50 watts, but can be made less by careful adjustment. Coil resistances may be obtained in the 1 to 2000 ohm range for voltages from 1 to 50 VDC.

Write today for further details and catalog of complete line.

Advance Relays

ADVANCE ELECTRIC & RELAY CO.
1260 West 2nd St., Los Angeles, California • Phone Michigan 9331

HEAT RESISTANT WIRES FOR EVERY APPLICATION . . .

TOUGH *and* RUGGED

Do your new circuit designs call for heat resistance wire that's tough and rugged—wire that can take it day after day through countless hours of operation? Then check Lewis Asbestos Covered Wire before you specify. Regardless of what your wire problem is—dropping excessive voltages—filament dropping resistor in the line—high current conductors, it doesn't matter, just . . .

HEATING UNITS
HEATING ELEMENTS
RESISTANCE LINE CORD
THERMOCOUPLE WIRE
ASBESTOS LEAD & FIXTURE WIRE
INSULATED RESISTANCE WIRE
FIBERGLAS INSULATED WIRE
WIRE TO ANY SPECIFICATIONS

Let Lewis Build The Wire For You

Send your electronic control, communications or appliance wiring specifications for a recommended solution by our engineers.

FOR A TRIAL ORDER OR A CARLOAD consult

THE LEWIS ENGINEERING CO.
Wire Division
NAUGATUCK CONNECTICUT

For LONG TROUBLE-FREE OPERATION Specify

N·W·L

CUSTOM-BUILT TRANSFORMERS AND ELECTRICAL COILS

Over 25 years experience in the manufacture of specials at cost that compares favorably with standard types. Built-in quality proved by years of actual use.

From 10VA to 300 KVA Dry-Type Only, Both Open and Encased, 1, 2, & 3 Phase 25 to 400 Cycles.

PROMPT DELIVERIES!

NOTHELFER
WINDING LABORATORIES
9 ALBERMARLE AVE., TRENTON 3, N. J.

THIS IS IT!

World-wide recognition for this outstanding line of electric soldering irons—

HEXACON

—specified by the big names for the TOUGH JOBS!

★ MINNEAPOLIS HONEYWELL
★ RADIO CORP. OF AMERICA
★ STROMBERG-CARLSON
★ WESTERN ELECTRIC
★ WESTINGHOUSE
★ EMERSON
★ KAISER
★ BENDIX
★ SPERRY,
etc.

PLUG OR SCREW TIPS
40 to 700 Watts
⅛" to 1⅛" Tip Dia.

Follow the leaders and you'll specify HEXACON! They'll efficiently solve your soldering problems too! Write for literature.

Here's the famous
HEXACON HATCHET TYPE

These irons feature better balance for reduced operator fatigue. Efficiency is stepped up, and quality of work is improved. The ideal iron for inaccessible and intricate jobs.

HEXACON ELECTRIC CO.
130 W. CLAY AVE., ROSELLE PARK, NEW JERSEY

should produce 350 million electron volts. Its magnet design will produce seven-eighths of the proton energy of the largest cyclotrons now under construction, while using about one-half of the steel and requiring only 60 percent of the electric power needed to operate the largest machines.

PHILIPS COMPANY of Eindhoven, Holland, was recently appointed world-wide distributor of Motorola's f-m two-way radiotelephone equipment.

Daniel E. Noble (left), Motorola vice-president, and I. Jill Schelling of Philips Co., discuss equipment

THE TEXAS COMPANY has made a $250,000 grant to the Massachusetts Institute of Technology for atomic research and training of nuclear scientists.

WESTINGHOUSE ELECTRIC CORP. announces that its latest type f-m transmitter will feed an f-m antenna atop the world's tallest structure, a 1,530-ft tower to be built near Des Moines, Iowa, by station KNRT.

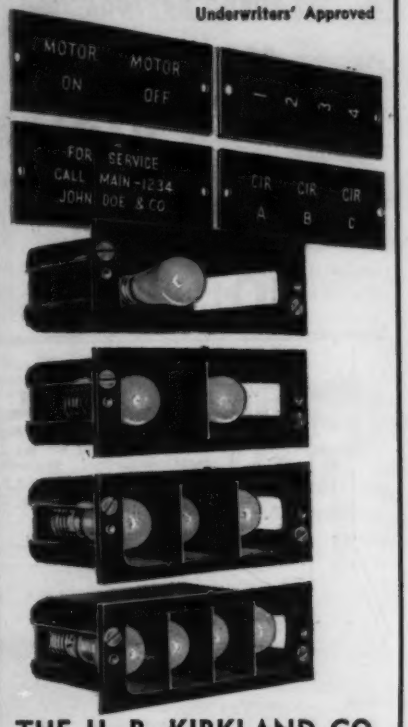
FURST ELECTRONICS, Chicago, Ill., manufacturers of specialized electronic instruments, have more than doubled floor space by moving to larger quarters in the same building.

TELETRAN CORP. was recently formed for the manufacture of television components. Offices are in New York City, with the factory at Ramsey, N. J.

VICKERS ELECTRIC DIVISION, VICKERS INC., at El Segundo, Calif., manufacturers of selenium rectifiers and self-generating photoelectric cells, has succeeded the Sele-

KIRKLAND
TYPE ML MULTIPLE LAMP INDICATORS

Underwriters' Approved



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Model MCM Master Midget Lever Switch

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- ☐ HB-3 Tube Handbook ($10.00)*. [B]
- ☐ RC-15 Receiving Tube Manual (35 cents). [C]
- ☐ Receiving Tubes for AM, FM, and Television Broadcast (10 cents). [D]
- ☐ Radiotron Designers Handbook ($1.25). [E]
- ☐ Quick Selection Guide, Non-Receiving Types (Free). [F]
- ☐ Power and Gas Tubes for Radio and Industry (10 cents). [G]
- ☐ Phototubes, Cathode-Ray and Special Types (10 cents). [H]
- ☐ RCA Preferred Types List (Free). [I]
- ☐ Headliners for Hams (Free). [J]

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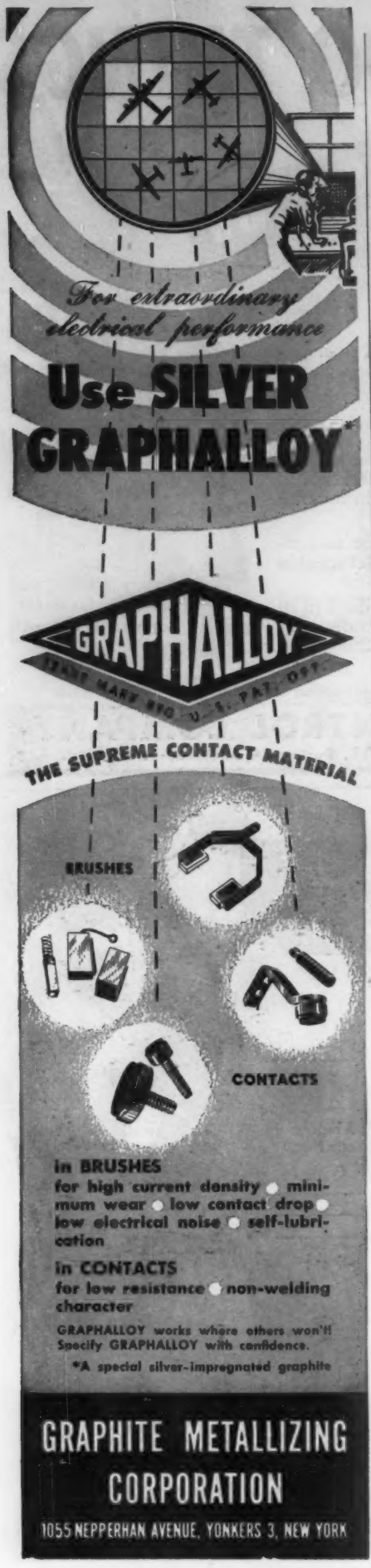
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nium Corp. of America, which was voluntarily dissolved.

LUMINOUS INDUSTRIES, INC., New York, N. Y., was established for the manufacture and distribution of luminous compounds and related products. It offers the industry complete engineering and research facilities in the fluorescent field.

THE DILKS CO., Seymour, Conn., has been organized to take over production of air column loudspeakers.

KARTRON, INC., manufacturers of microfilters and shorted-turn and open-circuit coil checkers, moved into their new plant in Huntington Beach, Calif.

TOBE DEUTSCHMANN CORP. has opened a new plant at Norwood, Mass., with increased facilities for the production of electrolytic capacitors.

New Tobe Deutschmann plant

ATLAS SOUND CORP., Brooklyn, N. Y., has increased facilities for the manufacture of sound equipment by annexing a building adjoining the original plant.

CONTINENTAL F-M NETWORK has added to its 31 stations the Dixie F-M Network of 10 stations in North and South Carolina.

PERSONNEL

W. R. G. BAKER of the General Electric Co. was elected vice-chairman of the Electrical Standards Committee of the American Standards Association.

LESTER L. LIBBY is chief engineer of newly formed Ohmega Labora-

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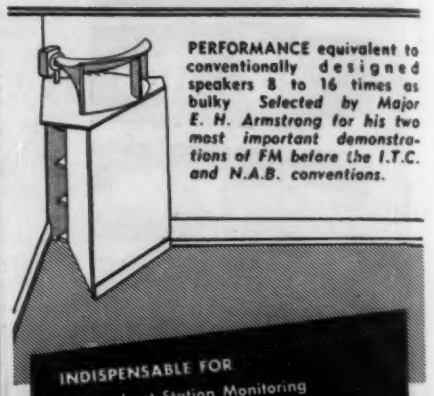
FREQUENCY RANGE 30 to 15,000 cycles



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Very thorough explanations of the theory involved and the mathematical methods used in the solution of transmission problems, with special attention to factors affecting the economy and efficiency of service such as maintenance of constant voltage at system termini and the causes and severity of faults. $5.50

Wave Guides

By L. G. H. Huxley

The first of a series of books on modern radio techniques developed largely during the war and heretofore not fully divulged. Both the theory and practical construction of wave guides as used in high-frequency equipment are fully explained here, including both the British and American experience. $4.75

Fundamental Electronics & Vacuum Tubes

By A. L. Albert

A new revised edition of a widely used text and engineering reference on the principles of electronic tubes and tube circuits, methods of analysis, and uses in both power and communication engineering. $6.00

● ● ● *and useful references*

An Introduction to Electronics

By Hudson. This masterly exposition of the modern theories underlying electronics, the construction of key devices, and their infinite number of uses is one of the best "introductions" ever presented on this subject. $3.30

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By Emery. A practical guide. The fundamentals are explained in clear, simple terms and worked-out examples show the use of principles in specific design problems and the prediction of circuit performance. $3.75

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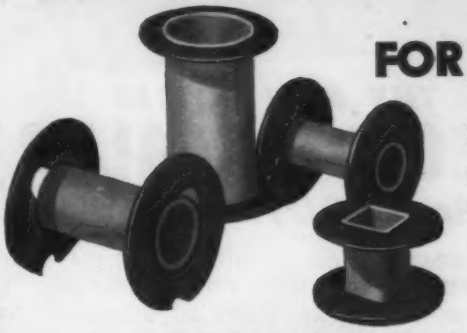

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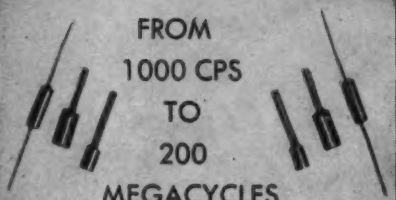

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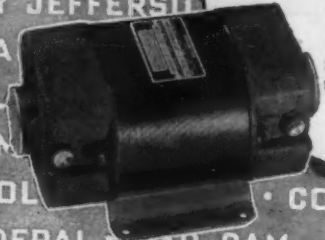

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tories, Inc., the developmental subsidiary of Kay Electric Co. He was formerly senior project engineer with Federal Telecommunication Laboratories.

JOHN J. GRESKO, newly appointed production manager of the Electron Tube Division of Sonotone Corp., Elmsford, N. Y., was formerly manager of the Sylvania receiving tube plant at Emporium, Pa.

CHARLES M. HOGAN has been appointed resident patent counsel in charge of radio and electronic patents of the Crosley Division, Avco Manufacturing Corporation.

Charles M. Hogan

P. B. Patton

PHILIPS B. PATTON was named West Coast engineering and sales representative of the Mobile Communications Division of Farnsworth Television & Radio Corp. He was previously acting chief engineer of the Common Carrier Engineering section of the FCC.

ALLAN W. PARKES, JR. has been placed in charge of the field engineering and sales department at Aircraft Radio Corp., Boonton, N. J. Before joining the corporation in 1927 he taught physics at Lafayette College and Harvard University.

EDWARD G. F. ARNOTT, electronic tube specialist on the research staff since 1940, is the new assistant director of research at the Westinghouse Lamp Division in Bloomfield, N. J.

THOMAS H. NEELY, a member of the Bell Laboratories technical

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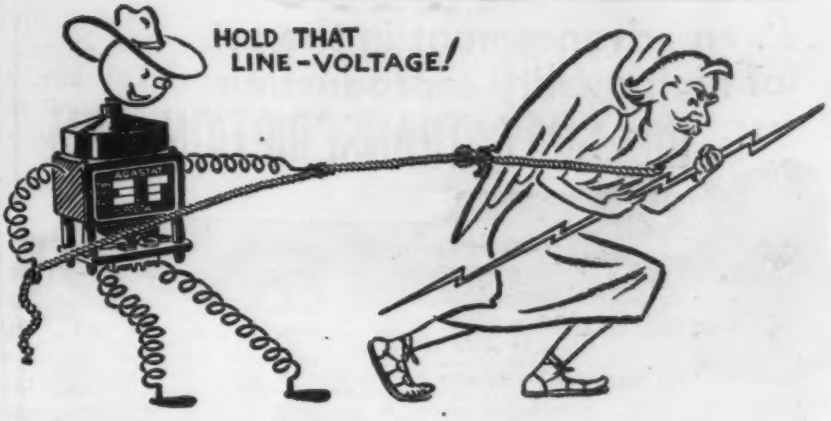

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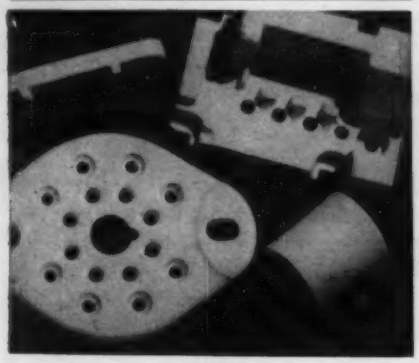

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Flexural Strength	10,500 lbs. per square inch
Modulus of Rupture	20,000 lbs. per square inch
Dielectric Strength	235 volts per mil
Dielectric Constant	6.42
Loss Factor	2.90
Power Factor	448

Frequency of 1 megacycle

Bulk Specific Gravity	2.684
Density (from above gravity)	0.096 lbs. per cubic inch
Hardness (Mohr scale)	7.0
Softening Temperature	2,350°F.
Linear Coefficient of Expansion	8.13x10—6
Moisture Absorption (ASTM D-116-42-A)	0.009%

Design engineers and manufacturers in the radio, electrical and electronic fields are finding in LAVITE the precise qualities called for in their specifications . . . high compressive and dielectric strength, low moisture absorption and resistance to rot, fumes, acids, and high heat. The exceedingly low loss-factor of LAVITE plus its excellent workability makes it ideal for all high frequency application.

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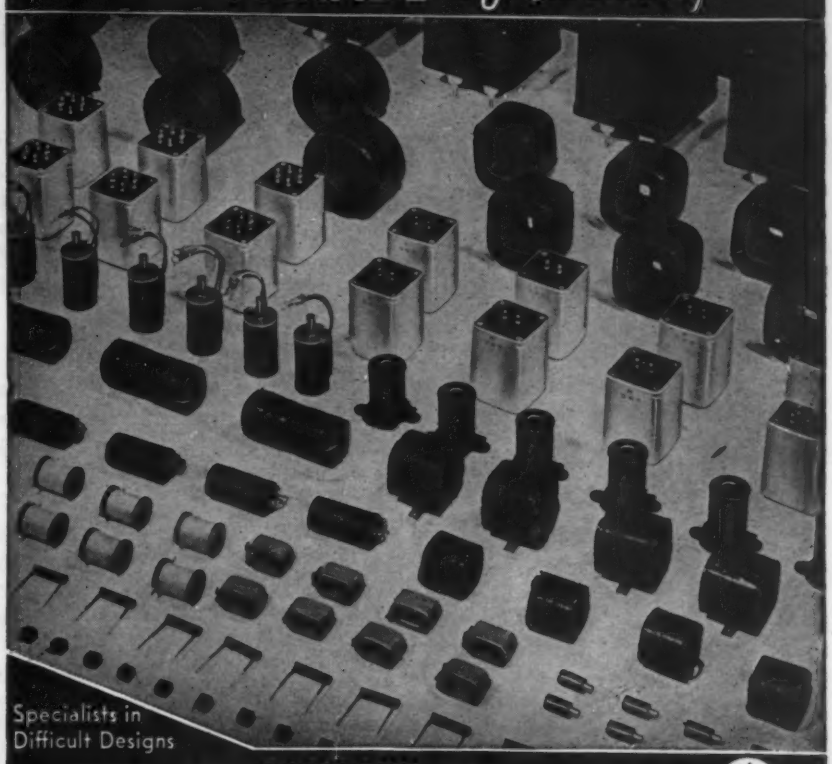

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staff, was placed in charge of the Electronic Warfare Battalion at the Naval Shipyard, Brooklyn, N. Y. The newly organized unit will train qualified personnel in all phases of electronics.

K. C. BLACK has joined the staff of Air Associates, Inc., Teterboro, N. J., as chief radio engineer. During the war he worked in Division 15 and later in Division 13 of NDRC, and for 11 years before that worked on development of repeater equipment for coaxial lines at Bell Telephone Laboratories.

K. C. Black

W. J. Morlock

WILLIAM J. MORLOCK, who for several years was responsible for theater sound equipment design at RCA, has been appointed division engineer of the specialty division of General Electric at Electronics Park.

H. B. FANCHER, actively engaged in design and development of television transmitters and microwave relays, is a newly appointed assistant section engineer of G-E's transmitter division, Electronics Park, Syracuse, N. Y.

RAGNAR HOLM was recently appointed consultant on the engineering staff of Stackpole Carbon Co., St. Marys, Pa. He is author of "Electric Contacts", written in Sweden; the English edition is now available in the U. S. through booksellers, particularly through Stechert and Hofner, 31 E. 10th St., New York.

KENNETH E. WEITZEL was recently appointed an application engineer of the Tube Division of G-E's Electronics Department with head-

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More than triple the effective power of the transmitter.

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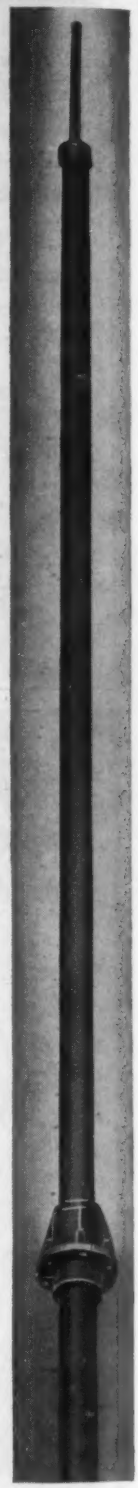
Permit the use of low power, low cost equipment.



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- Symmetrical design makes azimuth pattern circular.
- Can be fed with various types of transmission lines. Special fittings are available for special applications.
- Enclosed in non-metallic housing for maximum weather protection.

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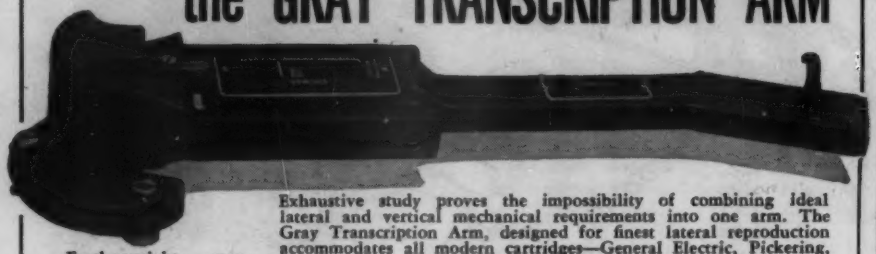

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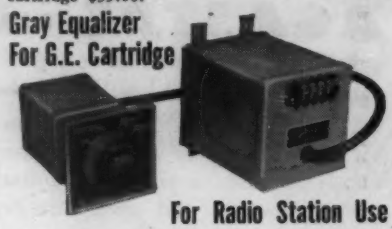

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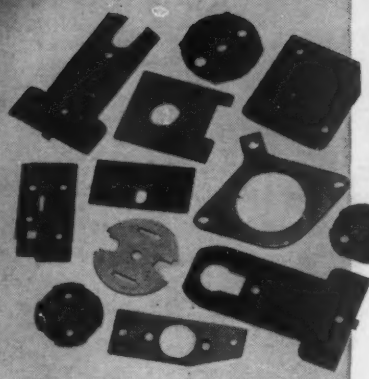

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quarters in Chicago. During the war he worked on applications of the G-E high-frequency lighthouse tube for wartime equipment.

RODNEY D. CHIPP, formerly radio facilities engineer for the American Broadcasting Company, has been named assistant engineer for the DuMont television network.

R. D. Chipp

D. W. Pugsley

DONALD W. PUGSLEY, formerly television receiver section leader, was named designing engineer with responsibility for technical design of television receivers at General Electric Co.

EDWARD H. REEVES has been named technical supervisor of f-m operations for WAAT-FM in Newark, N. J.

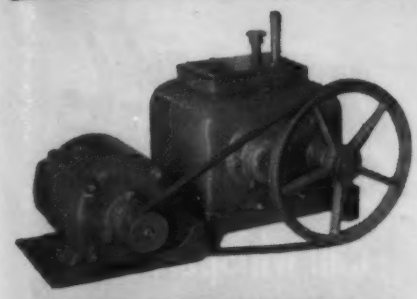
JOSEPH SLEPIAN, associate director of the Westinghouse Research Laboratories, was awarded the AIEE's Edison Medal for 1947.

THEODORE W. BUCHTER is now territorial service manager for United States Television Mfg. Co., working out of the company's main office in New York City.

L. ROBERT FISHER was named territorial service manager for the New Jersey and eastern Pennsylvania areas by United States Television Mfg. Corp. He was formerly field engineer for the Allen B. DuMont Laboratories.

HENRY L. DABROWSKY, former G-E development engineer, has been named technical supervisor of television for WATV, soon to occupy television channel 13 in Newark, N. J.

ALBERT R. HODGES, formerly patent



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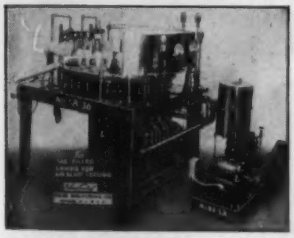

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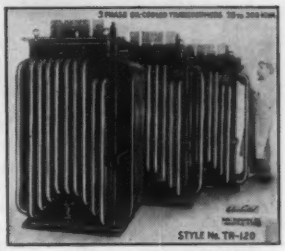

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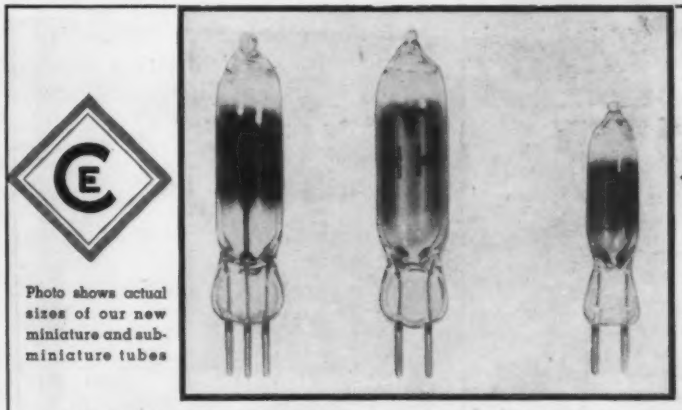

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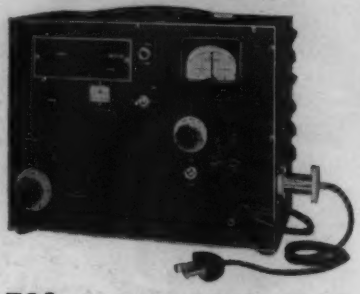

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BOONTON NEW JERSEY

attorney at Sperry Gyroscope Co., Inc., now handles patent prosecution and related matters in the radio and electronics field for Stromberg-Carlson Co., Rochester.

C. R. MINER has advanced from section leader to designing engineer, with responsibility for the technical design of Musaphonic, standard line, portable, contact, and export receivers at G-E's Syracuse plant.

C. R. Miner

N. F. Shofstall

N. F. SHOFSTALL was promoted from designing engineer to assistant division engineer of the G-E television receiver division.

J. E. KEISTER, associated with radar and television transmitter development at G-E since 1942, was appointed section engineer of the television and broadcast engineering section of General Electric's transmitter division at Electronics Park, Syracuse, N. Y.

J. E. Keister

G. F. Hussey, Jr.

GEORGE F. HUSSEY, JR., Vice Admiral, USN, (Ret.) and wartime chief of the Navy's Bureau of Ordnance, assumed his new duties Jan. 1, 1948 as administrative head of American Standards Association.

ARTHUR J. SANIAL is now chief engineer of Audio Equipment Co., Inc., a new firm formed to purchase patents, manufacturing rights, and inventory of the portable electric megaphones from Guided Radio Corp. and continue manufacture of these and other audio products.

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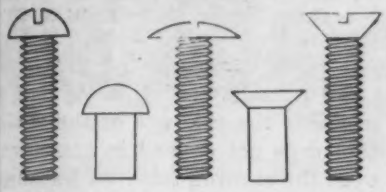

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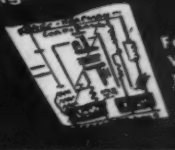

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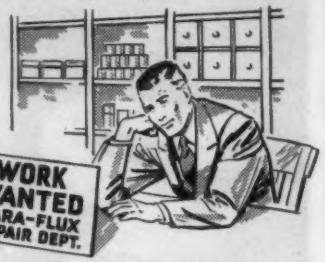

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Volume 27 of the MIT Radiation Laboratory Series, by ANTONIN SVOBODA. *McGraw-Hill Book Co., New York,* 1947, 359 *pages,* $4.50.

THE SUBJECT of this volume is probably the only one of the series that does not depend in some way upon the electron tube. At the same time, the principles outlined in the book may well be tied in economically to the control of, or be actuated by, tube devices. The author points out that the elementary integrators, component solvers, speedometers, and planimeters that can be built using the principles outlined can be expanded into mechanisms to perform more elaborate calculations. In the latter class would appear gunsights, bombsights, and automatic aircraft pilots. For the mechanical engineer engaged in the computing aspects of modern automatic electronic equipment the book should be most useful.—A. A. McK.

Automatic Regulation

BY WILLIAM R. AHRENDT AND JOHN F. TAPLIN. *Published by Ahrendt and Taplin, P. O. Box* 4673, *Washington* 20, *D. C.,* 1947, *Vol. I,* 207 *pages,* $3.50.

THE MATERIAL of this book, covering the fundamentals of servomechanisms and other types of regulators, is presented as an introduction to the second volume—in preparation—which will cover practicalities of specific systems. This present material has been used as a one-year course at the University of Maryland. A unified nomenclature has been adhered to throughout the presentation.

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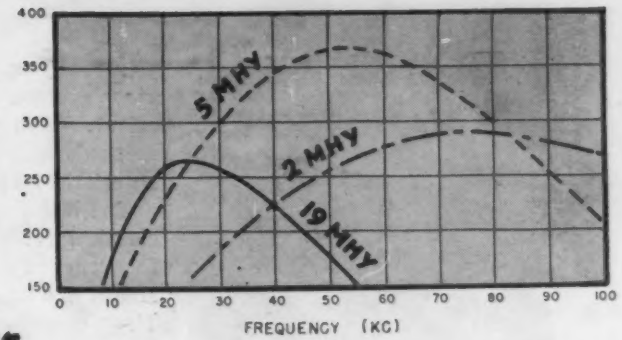

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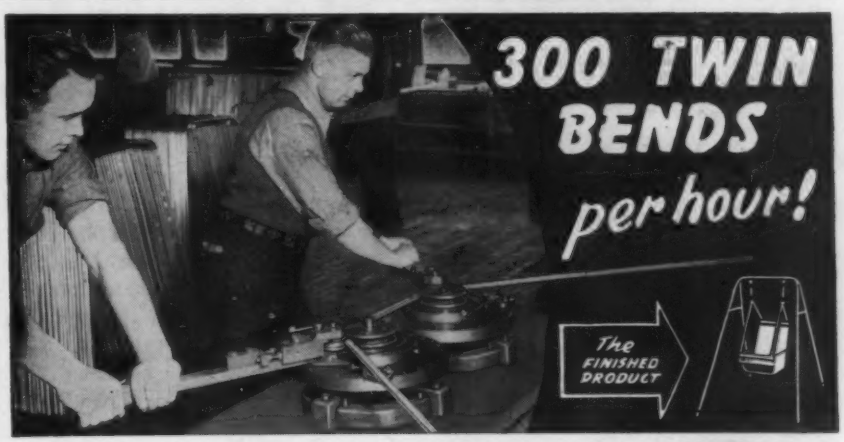

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sponse curves are presented for various systems so that the book constitutes both a guide to analytical methods and a reference to characteristic responses.

The last four chapters cover the classical (step function) approach, frequency spectrum analysis, and simple and multiple loop regulators. They concern system characteristics. In the two introductory chapters, the physical means (pneumatic hydraulic, mechanical and electronic) for realizing these characteristics are discussed. An appendix includes problems and their answers.—F. H. R.

Radio Handbook, 11th Edition

EDITED BY R. L. DAWLEY. *Editors and Engineers, Ltd., Santa Barbara, California*, 1947, 512 *pages*. $3.25 *postpaid*.

WHILE it is not necessary to be crazy to be a good radio amateur, it is definite help—thus proving the old cliche. For, as a class, the hams are about as crazy as man comes without being put away.

These operators, technicians, engineers go to great pains to build apparatus which is promptly torn down; they spend all night talking to other hams to whom they really have nothing to say; they purchase great quantities of surplus radio gear much of which they will never use; they are a menace to home life —but their value to the nation is so great and so well established that their status is secure even if their allocations are not.

If there is one thing the average ham is violent about it is his search for knowledge. He is in a constant turmoil endeavoring to improve his gear and its operation; he investigates every silly idea and makes many of them work. New regions of the spectrum are his happy hunting ground; he is a pioneer and an explorer.

Thus when one of the amateur handbooks, like the 11th Edition of the Radio Handbook or the ARRL book comes out, there is (or/should be) a rush to buy it. The new Radio Handbook is a help in the education direction for it is over 500 pages of facts. There are more than

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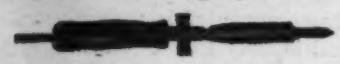

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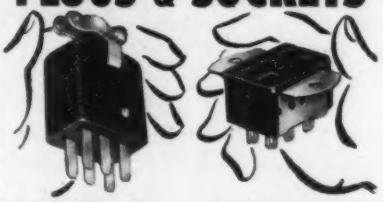

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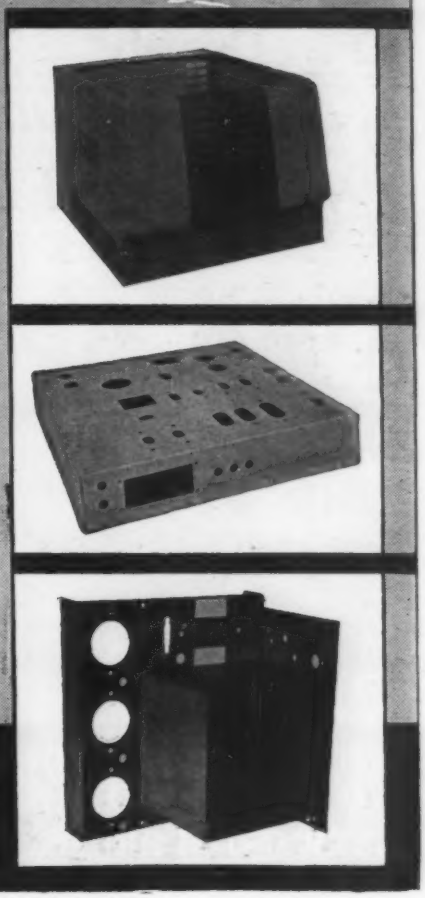

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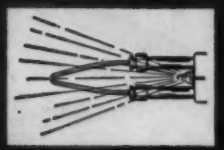

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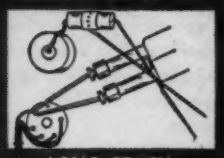

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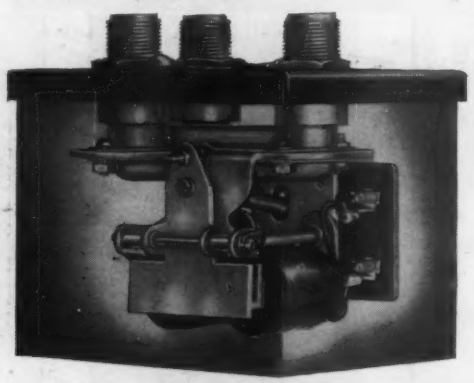

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Electronic Circuits and Tubes

BY THE ELECTRONICS TRAINING STAFF OF CRUFT LABORATORY. *McGraw-Hill Book Co., New York, N. Y.*, 1947, 948 *pages*, $7.50.

THIS book is an outgrowth of the notes used in a basic electronics course given to radar officers of the armed forces during World War II. The book surveys the field of electronics and electron tubes as well as circuits used in the field of communications. The material covers basic a-c theory and circuits, transients, electron tubes, amplifiers, oscillators, modulation, demodulation, radio receivers, and special timing circuits. Due to this wide coverage, the material is not as detailed as it is in books dealing with specialties. However, from the pedagogical point of view, the subject matter is admirably presented and the continuity is very good despite the fact that eleven authors collaborated.

The reader is expected to have a good knowledge of the calculus and should be familiar with a-c circuits because the circuit material in the book does not seem sufficient for a first exposure. The book seems suited as a text for seniors in electrical engineering who are taking a course in communication electronics. Because of its excellent presentation, the book may also be used as a source of information outside formal course work by those who wish to study the field on their own. The greatest weakness of the book is the lack of problems which can be used by the reader. Also, the references to outside reading are not as plentiful as they might be.

The text compares quite favor-

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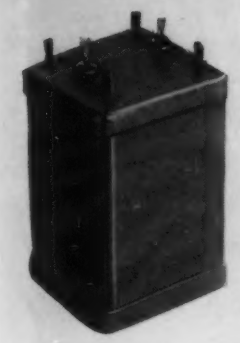

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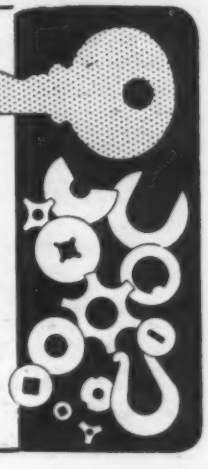

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ably with other books in the field, being more modern and up-to-date than some. On the whole, this book is well recommended because it is well written and because it covers the fundamentals of the field of electronic circuits and tubes effectively.—JOHN R. RAGAZZINI, *Columbia University, New York, N. Y.*

New Weapons for Air Warfare

EDITED BY JOSEPH C. BOYCE, *Special Assistant to the Chairman, NDRC, and Professor of Physics, New York University. Little, Brown and Co. in association with The Atlantic Monthly Press, Boston,* 1947, 292 *pages,* $4.00.

THIS volume, second in the series on the history of the Office of Scientific Research and Development, covers fire control, proximity fuzes and guided missiles. (The first of the series is the Pulitzer-Prize winning "Scientists Against Time" —ELECTRONICS, p 302 Dec. 1947.) As a record of the organization and operation of the divisions concerned with these developments, this book not only gives credit to those whose foresight and singleness of purpose made the projects successful, but it also shows how cooperation without coercion constitutes the core of American scientific, engineering and industrial productivity. For those workers who saw only portions of the projects in which they participated, this book and the others of the series give a coordinated picture.

In addition to describing in a nontechnical manner the obstacles and achievements of various developments, the book tells something of the use of the developments in winning the war. For example, "The story is one of the outstanding romances of the war. The buzz-bomb was defeated by a combination of these OSRD-produced weapons—the VT-fuze, the M-9 director and the SCR-584 radar. In the matching of wits and weapons, American science, industry and the military beat decisively this creation of the much-vaunted German scientists." The experience of managing research projects that is reported in this volume will be of value to any one

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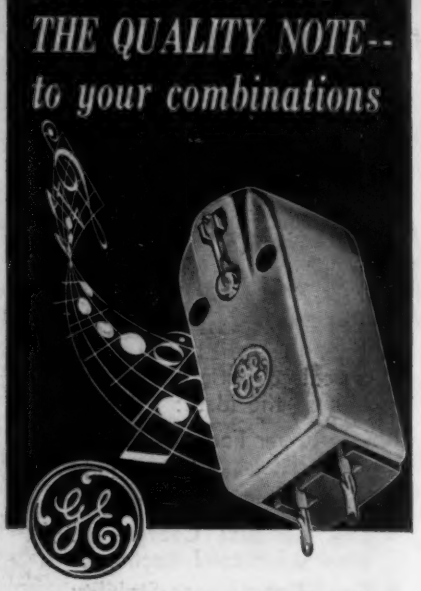

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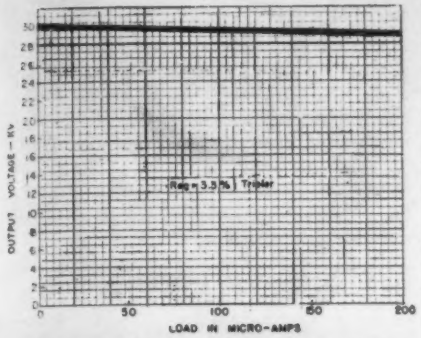

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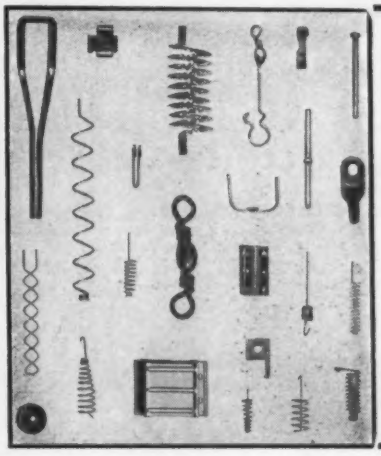

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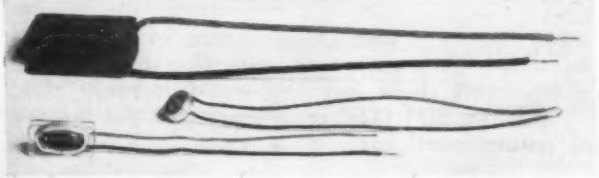

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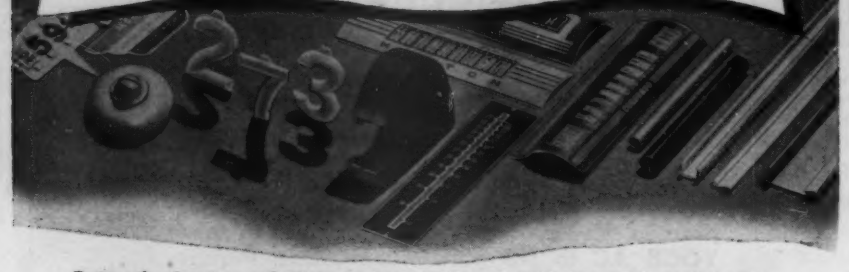

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Books Received for Review

ELEMENTS OF NOMOGRAPHY. By R. D. Douglass, Professor of Mathematics, and D. P. Adams, Assistant Professor of Graphics, both of Massachusetts Institute of Technology. McGraw-Hill Book Co., Inc., 1947, 209 pages, $3.50. Theory and construction of nomographic charts, including a chapter on the circle nomograph which is particularly useful in representing electrical circuit relations.

INSTRUMENT AND CONTROL MANUAL FOR OPERATING ENGINEERS. By Eugene W. F. Feller. McGraw-Hill Book Co., Inc., New York, N. Y., 1947, 426 pages, $6.00. Basic principles of control, and construction and operation of liquid-level, pressure, temperature, speed and humidity indicators and controllers. Though only a few electronic circuits are covered, the material is essential reference reading for those applying electronic controls to industrial instrumentation and automatic control problems.

PERPETUAL TROUBLESHOOTER'S MANUAL, Vol. XVI. John F. Rider Publisher, Inc., New York 16, N. Y., 1947, 736 pages plus 48-page How It Works booklet with index, $6.60. Radio receiver and record changer service data from 94 manufacturers, collected and arranged for easy reference, with clarified schematics showing circuits set up for each position of band-changing switch. Booklet analyzes new developments in f-m receiving antennas, selenium rectifier circuits, f-m preemphasis and deemphasis, f-m tuning indicators, special avc circuits, television power supplies, and battery charging circuits.

PROCEEDINGS OF THE SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS, Vol. V, No. 1. Published by Society for Experimental Stress Analysis, Central Square Station, P. O. Box 168, Cambridge 39, Mass., 1947, 136 pages, $6.00. Membership roster and 15 papers, two of which are on radio telemetering and one on x-ray techniques. Both telemetering topics have been covered in ELECTRONICS.

NOMOGRAPHY. By A. S. Levens, Associate Professor, University of California. John Wiley & Sons, Inc., New York, 1948, 176 pages, $3.00. Construction of alignment and proportional charts is developed from geometry of seven generally encountered types of equations, with examples from various branches of engineering. A chapter on shortcuts in constructing charts presents especially useful approaches; a chapter on using determinants in constructing charts presents especially powerful approaches.

METHODS OF ALGEBRAIC GEOMETRY. By W. V. D. Hodge and D. Pedoe, both of the Cambridge faculty. Cambridge University Press, 1947, $6.50; Book I, Algebraic Preliminaries, 173 pages; Book II, Projective Space, 258 pages (bound in a single volume). Mathematics of fields using methods of matrices, and modern algebra are developed in Book I. Space is dealt with algebraically and synthetically in Book II. The methods dealt with are among those by which waveguide and multimesh circuits and modern theories of communication are studied.

RADIO TUBE VADE MECUM 1948, 7th EDITION, prepared and published by P. H. Brans, Ltd., Antwerp, Belgium, 1948; 294 pages, available in U.S.A. through Editors & Engineers, Ltd., 1300 Kenwood Road, Santa Barbara, Calif., $3.10. The method of indexing this list of the world's radio tubes has been revised; identical types are grouped by heater voltage. Additional types, including transmitting, cathode-ray and photoelectric tubes have been included. The expanded edition is published in two parts so that one can conveniently open to the basing diagrams and the index simultaneously.

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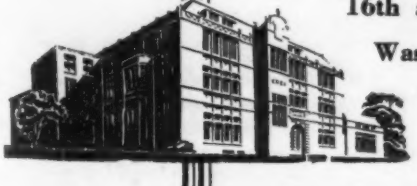

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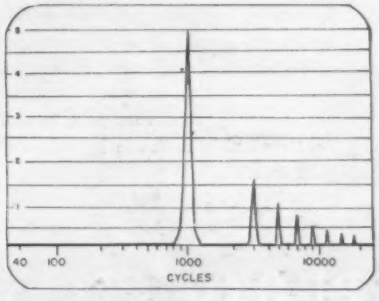

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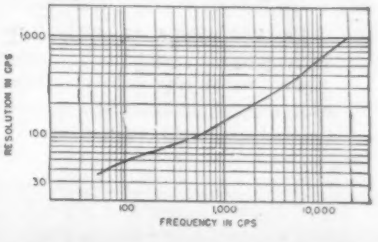

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Backtalk

This department is operated as an open forum where our readers may discuss problems of the electronics industry or comment upon articles which ELECTRONICS has published.

Suppressor Characteristics

DEAR SIRS:

Regarding L. G. McCracken's paper on the Dynamic Noise Suppressor (page 114 this issue):

Dr. Guillemin's formulae, from which McCracken's analysis is derived, are based upon the assumption that the filters are terminated in their iterative impedances and are dissipationless. Neither of these conditions can apply in the Dynamic Noise Suppressor, since the impedances shift with the cutoff frequency. Furthermore, practical circuit elements are not dissipationless, and the reactance tube in particular has a complicated power factor characteristic which varies with the cutoff frequency.

In actual practice, the terminating impedances for the Dynamic Noise Suppressor and the operating characteristics of the reactance tube are selected to provide best overall characteristics. Both Dr. Guillemin and I are of the opinion that because of the complexity of any satisfactory analysis of the reactance tube circuit, a mathematical analysis should not be relied upon for determining the exact response curves.

Bearing in mind these limitations, McCracken's analysis seems to demonstrate satisfactorily how the system works. Whether this demonstration is more or less useful than a simpler inspection of the general characteristic circuits is entirely a matter of opinion.

It should be noted that the dynamic-band-pass system is useful in any application where the signal is changing in character, so that the pass band may include only the range required by the signal. This is entirely independent of the ear. However, a further degree of sup-

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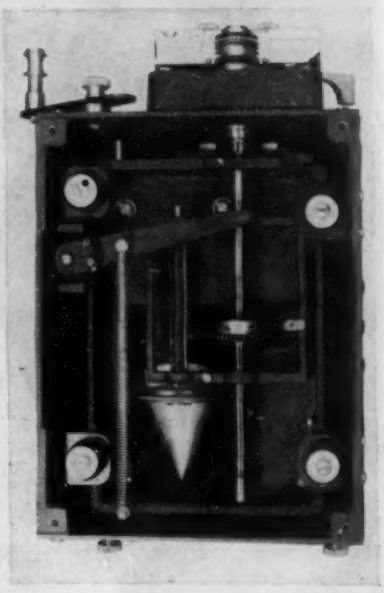

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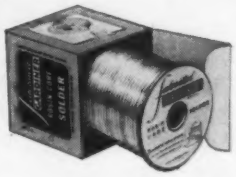

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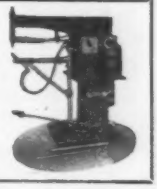

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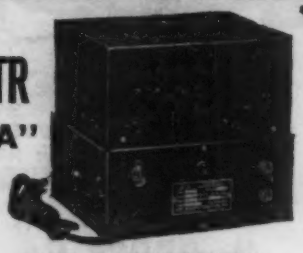

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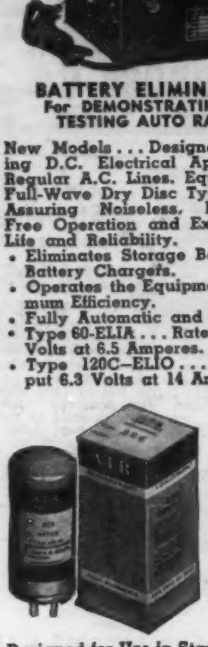

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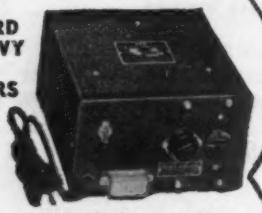

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pression can be obtained when using the dynamic-band-pass system in connection with signals which are to be heard by the ear, since it is then possible to further restrict the bandwidth so that it includes only those components which are present at a sufficient amplitude to be heard by the ear.

In other words, the dynamic-band-pass system is useful under conditions where either the signal or the detecting device, in this case the ear, has characteristics which are not constant. In the case of listening to music, both the signal and the ear characteristics are varying, so that the Dynamic Noise Suppressor is particularly well suited for this application.

H. H. SCOTT
Cambridge, Mass.

Predetermined Counters

DEAR SIRS: THE appearance of my article "Predetermined Counters for Process Control" in the February 1948 ELECTRONICS gave me great pleasure. Unfortunately however there are several mistakes in the exponential notation that make the explanation of the counter's operation seem to be contradictory.

Page 88, column 1, line three should read "aperiodic", the expressions on page 89, column 2, lines 14, 22, and 24, and column 3, line 8 should all have been printed "2^{N-1}th." Page 91, column 3, line 44 and following should read "ground return of all four righthand binary-stage grids in a single decade, as shown in Fig. 6." Page 92, column 1, line 56 should read "isolated".

On Fig. 2, in stages 2 and 4, the lefthand cathodes should be marked *A* and the righthand ones *B*. On Fig. 6, the relay is Type 275-B, and the grid resistor in the delay multivibrator (lower right) should be 3.3 megohms. This last error probably arose from the lack of standardization of the abbreviation for thousand, some using "M", some using "K".

RICHARD J. BLUME
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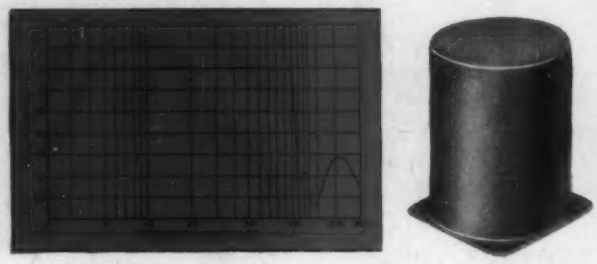

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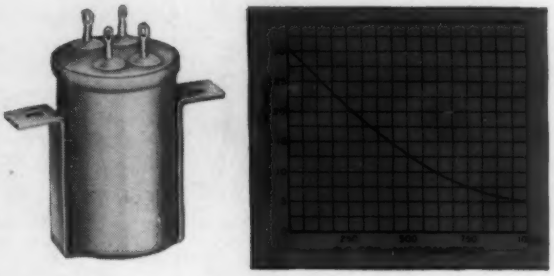

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ELECTRONICS, May, 1948, Vol. 21; No. 5. Published monthly, with an additional issue in June, price 75c a copy. Directory issue $2.00. Allow at least ten days for change of address. All communications about subscriptions should be addressed to the Director of Circulation.
Subscription rates—United States and possessions, $6.00 a year, $9.00 for two years, $12.00 for three years. Canada (Canadian funds accepted), $7.00 a year, $11.00 for two years, $14.00 for three years. Pan American countries $10.00 for one year, $16.00 for two years, $20.00 for three years. All other countries $15.00 for one year, $30.00 for three years. Please indicate position and company connection on all subscription orders. Entered as Second Class matter August 29, 1936, at Post Office, Albany, New York, under the Act of March 3, 1879. BRANCH OFFICES: 520 North Michigan Avenue, Chicago 11, Ill.; 68 Post Street, San Francisco 4; Aldwych House, Aldwych, London, W. C. 2; Washington, D. C. 4; Philadelphia 3; Cleveland 15; Detroit 26; St. Louis 8; Boston 16; Atlanta 3, Ga.; 621 So. Hope St., Los Angeles 14; 738-9 Oliver Building, Pittsburgh 22.

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